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Chromosome counts and karyotype reports from *Fimbristylis* (Cyperaceae) in Thailand

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ABSTRACT

The somatic chromosome numbers and karyotype of Thai *Fimbristylis* species were determined from root tips. The chromosome counts and karyotype formulae are 2n=20 (16m+4sm) for *F. argentea*, 2n=26 (2M+10m+14sm) for *F. dichotoma*, 2n=4 (2m+2sm) for *F. pubisquama*, 2n=10 (6m+4sm) for *F. insignis*, 2n=10 (8m+2sm) for *F. eragrostis*, *F. fusca*, *F. littoralis*, *F. ovata* and *F. umbellaris*, and 2n=10 (4m+6sm) for *F. thomsonii*. Chromosome numbers of *F. eragrostis*, *F. fusca*, *F. insignis*, *F. pubisquama* and *F. thomsonii* are newly reported. The present study determined several karyotype asymmetry values. In addition, correlation between the karyotype asymmetry values were shown in this study. The dispersion diagram was found based on A1 and A2. The Stebbins categories of *Fimbristylis* investigated taxa were 3A, 4A and 4B.

KEYWORDS: Chromosome number, Cyperaceae, *Fimbristylis*, karyotype.

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INTRODUCTION

Fimbristylis Vahl is a large genus of Cyperaceae belonging to tribe Abildgaardieae. The genus comprises about 382 species worldwide (Govaerts *et al.*, 2019) and is distributed mainly in the tropical and subtropics, with the greatest number in Southeast Asia and Northeastern Australia. It consists of annual and perennial plants. There are 63 species of *Fimbristylis* in Thailand, of which three are recently reported (Simpson & Koyama, 1998; Maxwell, 2002; Wangwasit *et al.*, 2012; Wangwasit *et al.*, 2017). The chromosome numbers of 63 *Fimbristylis* species have been reported (Tanaka, 1939; Sharma & Bal, 1956; Sanyal & Sharma, 1972; Hsu, 1972; Rath & Patnaik, 1974; Nijalingappa, 1975a; 1975b; 1977; Subramanian, 1988; Bir *et al.*, 1992; Yano & Hoshino, 2006b; Roalson, 2008; Uchiyama *et al.*, 2010). The chromosome count varied from 2n=6 in *F. umbellaris* (Lam.) Vahl (Rath & Patnaik, 1977) to 2n=52 in *F. cymosa* R.Br. (Yano & Hoshino, 2006b). The chromosome size varied from 1.5 to above 3 µm (Bir *et al.*, 1986). Hoshino *et al.* (2000) reported that the chromosomes of Cyperaceae possessed non-localized centromeres and there are no visible primary constrictions. The cytological data for Thai *Fimbristylis* species are comparatively few, with 16 reported covering only 26% of the Thai taxa (Tanaka, 1939; Sharma & Bal, 1956; Hsu, 1972; Sanyal & Sharma, 1972; Rath & Patnaik, 1974; Nijalingappa, 1975a; 1975b; Subramanian, 1988; Roalson, 2008; Saensouk & Saensouk, 2018). Thus, the aim of the present investigation is to report the chromosome number and to analyze karyotype characteristics of Thai *Fimbristylis*.

MATERIAL AND METHODS

Cytological observations were conducted on ten Thai *Fimbristylis* species, eight of them have never been examined before. Voucher specimens were deposited in Mahasarakham University Herbarium (MSUT) (Table 1). Somatic chromosomes were observed from root-tip meristematic cells. The root tips were fixed in a solution of acetic acid and ethyl alcohol (1:3) for 24 hours and stored in 70% alcohol under refrigeration. The samples were squashed in 2% acetocarmine. Chromosome numbers were determined from ten cells under a light

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microscope (Zeiss series model Axiostar plus). The best cells were photographed at 1000x magnification. Karyotype formula was determined based on centromere position (Levan *et al.*, 1964). The relative length (RL), centromeric index (CI) and arm ratio (AR) were computed for karyotype and idiogram contributions. The karyotype symmetry was determined by the Stebbins classification (Stebbins, 1971). The interchromosomal asymmetry index (A2) (Zarco, 1986) and coefficient of variation of chromosome length (CV_{CL}) (Paszko, 2006) were estimated. The intrachromosomal asymmetry indices were calculated using intrachromosomal asymmetry index A1 (Zarco, 1986), total form percentage (TF%) (Huziwara, 1962), centromeric gradient (CG) (Lavania & Srivastava, 1992), index of karyotype asymmetry (Syi) (Greilhuber & Speta, 1976, Venora *et al.*, 2002), Arano index of karyotype asymmetry (AsK%) (Arano, 1963) and coefficient of variation of the centromeric index (CV_{CI}) (Paszko, 2006). Also, the dispersion index (DI) (Lavania & Srivastava, 1992) and asymmetry index (AI) (Paszko, 2006) were examined. The Spearman correlation for asymmetry was analyzed using SPSS ver.17.0. Correlation was elucidated at 0.01.

RESULT AND DISCUSSION

The results indicated that the chromosome numbers of the ten *Fimbristylis* taxa are 2n=4–26. The comparison between the present study and previous records are summarized in Table 1. The studied taxa have median point (M), median (m) and submedian (sm) chromosomes. The base number (x), karyotype formula, chromosome length range (CLR), percentage of the chromosomes with arm ratio of less than 2:1, karyotype formulas, Stebbins classification, chromosome length (LT), arm ratio (AR), relative length (RL) and centromeric index (CI) were also measured (Tables 2–3). Karyotype asymmetry based on the interchromosomal asymmetry indices, which were A2 and CV_{CL}, the intrachromosomal asymmetry indices including A1, TF%, CG, Syi, AsK% and CV_{CI} and the two types of asymmetry using AI and DI are presented in Table 4. Images of the metaphase chromosomes and idiograms of ten *Fimbristylis* taxa are presented in Figs.1–2. The Spearman correlation for karyotype asymmetry is shown in Table 5 and the dispersion diagram is expressed in Fig. 3.

Section *Abildgaardia*
***Fimbristylis ovata* (Burm.f.) J.Kern**

The somatic chromosome number is 2n=10, which is congruent with Nijalingappa (1975b). *F. ovata* has eight median (m) and two submedian (sm) chromosomes. The shortest chromosome length is 2.51 µm and the longest chromosome length is 3.34 µm. The arm ratio ranges from 1.11–1.78 µm (Table 2), while the relative length ranges from 9–11.96% (Table 3). The Stebbins category is 4A.

Section Cymosae
***F. insignis* Thwaites**

The somatic chromosome number is 2n=10, which is the first reported for the taxa. The species has six median (m) and four submedian (sm) chromosomes. The shortest chromosome length is 2.50 µm and the longest chromosome length is 3.25 µm. The arm ratio ranges from 1.30–1.71 µm (Table 2), while the relative length ranges from 8.90–11.54% (Table 3). The Stebbins category is 4B.

Section Dicheostylis
***F. pubisquama* J.Kern**

The somatic chromosome number is 2n=4, which is the first report for this taxon. *Fimbristylis pubisquama* has two median (m) and two submedian (sm) chromosomes. The shortest chromosome length is 4.36 µm and the longest chromosome length is 4.87 µm. The arm ratio ranges from 1.56–2.28 µm (Table 2), while the relative length ranges from 23.57–26.42% (Table 3). The Stebbins category is 3B.

Section *Fimbristylis*
***F. dichotoma* (L.) Vahl**

The somatic chromosome number is 2n=26. The count disagrees with the previous investigations which were 2n=20, 2n=10, 2n=12, 2n=32 and 2n=28 (Sanyal & Sharma, 1972; Sharma & Bal, 1956; Hsu, 1972; Subramanian, 1988; and Saensouk & Saensouk, 2018, respectively). *Fimbristylis dichotoma* has 12 median (m), 12 submedian (sm) and two median point (M) chromosomes. The shortest chromosome length is 1.01 µm and the longest chromosome length is 1.82 µm. The arm ratio ranges from 1–2.64 µm (Table 2), while the relative length ranges from 2.7–4.87% (Table 3). The Stebbins category is 3B.

Table 1. Species examined, chromosome numbers and voucher information of the Thai *Fimbristylis* taxa studied.

Species and voucher specimens	Chromosome numbers in this study (2n)	Previous report (2n)
F. ovata (Burm.f.) J.Kern	10	10 (Nijalingappa, 1975b)
(W.Z 052)		
F. insignis Thwaites	10	-
(W.Z 038)		
F. pubisquama J.Kern	4	-
(W.Z 053)		
F. dichotoma (L.) Vahl	26	20 (Sanyal & Sharma, 1972)
(W.Z 014)		10 (Sharma & Bal, 1956)
		12 (Hsu, 1972)
		32 (Subramanian, 1988)
		28 (Saensouk & Saensouk, 2018)
F. eragrostis (Nees & Meyen) Hance (W.Z 105)	10	-
F. fusca Benth. ex C.B.Clarke	10	-
(W.Z 059)		
F. littoralis Gaudich (*F. miliacea* in Simpson and Kayama, 998)	10	10 (Sanyal & Sharma, 1972)
(W.Z 115)		
F. umbellaris (Lam.) Vahl	10	20 (Saensouk & Saensouk, 2018)
(W.Z.092)		6 (Rath & Patnaik,1977)
F. argentea (Rottb.) Vahl	20	20 (Bir *et al*., 1992)
(W.Z 089)		20 (Nijalingappa, 1975a)
F. thomsonii Boeckeler	10	-
(W.Z 131)		

Table 2. Somatic chromosome number, base number (x), chromosome length range (CLR), arm ratio (AR), percentage of the chromosomes with arm ratio of less than 2:1, karyotype formula and Stebbins classification of *Fimbristylis* taxa

Species	**2n**	**x**	**CLR (µm)**	**AR (µm)**	**Karyotype**	**<2:1**	**Stebbins**
F. ovata	10	5	2.51–3.34	1.11–1.78	4m+1sm	1	4A
F. insignis	10	5	2.50–3.25	1.30–1.71	3m+2sm	1	4B
F. pubisquama	4	5	4.36–4.87	1.56–2.28	1m+1sm	0.5	3B
F. dichotoma	26	5	1.01–1.82	1.00–2.64	6m+6sm+1M	0.7	3B
F. eragostis	10	5	1.86–3.02	1.49–2.36	4m+1sm	0.8	3B
F. fusca	10	5	2.19–2.84	1.31–1.90	4m+1sm	1	4B
F. littoralis	10	5	1.82–2.15	1.17–1.93	4m+1sm	1	4A
F. umbellaris	10	5	2.18–2.85	1.20–1.82	4m+1sm	1	4A
F. argentea	20	10	1.38–2.16	1.07–2.76	7m+3sm	0.9	3B
F. thomsonii	10	5	3.27–4.05	1.22–2.58	2m+3sm	0.6	3B

Table 3. Karyomorphological parameters: chromosome length (LT) (μm), arm ratio (AR), relative length (RL) and centromeric index (CI) of *Fimbristylis* taxa

F. ovata (4m+1sm)

Pair No.	LT	AR	RL (%)	CI	Type
1	3.34	1.27	11.96	43.92	m
2	2.81	1.51	10.05	39.88	m
3	2.71	1.78	9.72	36.01	sm
4	2.59	1.11	9.28	47.36	m
5	2.51	1.18	9	45.78	m

F. insignis (4m+1sm)

Pair No.	LT	AR	RL (%)	CI	Type
1	3.25	1.57	11.54	38.92	m
2	2.91	1.30	10.35	43.44	m
3	2.73	1.58	9.71	38.73	m
4	2.67	1.70	9.49	36.69	sm
5	2.50	1.71	8.90	37.14	sm

F. pubisquana (1m+1sm)

Pair No.	LT	AR	RL (%)	CI	Type
1	4.87	1.56	26.42	39.10	m
2	4.36	2.28	23.57	30.60	sm

F. dichotoma (6m+6sm+1M)

Pair No.	LT	AR	RL (%)	CI	Type
1	1.82	2.31	4.87	30.03	sm
2	1.77	2.01	4.76	33.25	sm
3	1.72	1.60	4.63	38.43	m
4	1.53	1.90	4.13	34.51	sm
5	1.52	2.45	4.09	28.87	sm
6	1.47	1.49	3.95	40.36	m
7	1.44	1.00	3.85	49.92	M
8	1.42	2.64	3.82	27.45	sm
9	1.35	1.70	3.63	37.33	m
10	1.30	1.47	3.50	40.41	m
11	1.18	1.46	3.10	40.83	m
12	1.09	1.87	2.93	34.85	sm
13	1.01	1.59	2.70	38.20	m

F. eragrostis (4m+1sm)

Pair No.	LT	AR	RL (%)	CI	Type
1	3.02	2.36	12.91	29.77	sm
2	2.56	1.52	10.94	39.59	m
3	2.26	1.59	9.67	38.70	m
4	1.99	1.49	8.52	40.11	m
5	1.86	1.55	7.96	39.38	m

F. fusca (4m+1sm)

Pair No.	LT	AR	RL (%)	CI	Type
1	2.84	1.51	11.34	47.13	m
2	2.62	1.31	10.52	48.71	m
3	2.51	1.90	10.15	37.87	sm
4	2.31	1.33	9.22	49.34	m
5	2.19	1.52	8.78	44.33	m

F. littoralis (4m+1sm)

Pair No.	LT	AR	RL (%)	CI	Type
1	2.15	1.23	10.77	44.88	m
2	2.09	1.32	10.47	43.02	m
3	2.06	1.17	10.31	46.08	m
4	1.86	1.55	9.34	39.30	m
5	1.82	1.93	9.11	34.21	sm

F. umbellaris (4m+1sm)

Pair No.	LT	AR	RL (%)	CI	Type
1	2.85	1.32	11.12	46.53	m
2	2.71	1.82	10.70	37.79	sm
3	2.58	1.33	10.07	46.61	m
4	2.45	1.31	9.62	45.88	m
5	2.18	1.20	8.49	49.31	m

F. argentea (7m+3sm)

Pair No.	LT	AR	RL (%)	CI	Type
1	2.16	1.81	6.10	35.74	sm
2	2.02	1.10	5.70	47.55	m
3	1.94	1.67	5.50	37.46	m
4	1.90	1.12	5.35	47.09	m
5	1.84	1.36	5.20	42.51	m
6	1.72	1.73	4.90	36.60	sm
7	1.68	1.07	4.70	48.27	m
8	1.57	1.24	4.45	44.73	m
9	1.46	1.56	4.10	39.05	m
10	1.38	2.76	3.90	26.70	sm

F. thomsonii (2m+3sm)

Pair No.	LT	AR	RL (%)	CI	Type
1	4.05	2.58	11.42	27.95	sm
2	3.59	1.22	10.12	45.14	m
3	3.53	1.76	9.95	36.28	sm
4	3.30	1.66	9.30	37.55	m
5	3.27	2.24	9.20	30.82	sm

Table 4. Arano index of karyotype asymmetry (AsK%), Index of karyotype asymmetry (Syi), centromeric gradient (CG), coefficient of variation of chromosome length (CV_{CL}), coefficient of variation in centromeric index (CV_{CI}), dispersion index (DI), asymmetry index (A1, A2, AI), total form percentage (TF%) for *Fimbristylis* species.

Species	AsK	Syi	CG	CV_{CL}	CV_{CI}	DI	A1	A2	AI	TF%
F. pubisquama	64.95	54.180	35.064	1.190	1.436	0.417	0.465	0.012	0.017	35.102
F. ovata	57.45	74.048	42.544	0.824	1.176	0.35	0.259	0.008	0.009	42.545
F. thomsonii	64.61	54.847	35.390	0.281	2.535	0.071	0.451	0.002	0.006	35.391
F. umbellaris	60.77	71.621	43.442	14.016	23.451	1.346	0.283	0.140	3.283	43.713
F. insignis	60.88	64.193	39.082	2.631	5.655	1.028	0.359	0.026	0.148	39.095
F. fusca	64.84	66.914	43.384	20.809	33.920	9.027	0.331	0.208	7.058	43.398
F. eragostis	63.70	58.587	36.943	2.654	5.200	0.980	0.415	0.026	0.138	36.926
F. dichotoma	63.79	56.673	36.147	1.116	0.549	0.403	0.434	0.111	0.006	36.200
F. argentea	58.82	69.090	40.837	2.092	3.456	0.854	0.310	0.021	0.072	40.849
F. littoralis	58.24	71.686	41.733	1.052	1.927	0.439	0.284	0.010	0.020	41.755

Table 5. Spearman correlation of asymmetry indices.

Correlations

	AsK%	Syi	CG	CV_{CL}	CV_{CI}	DI	A1	A2	AI	TF
AsK	1	-.838**	-.613	.243	.247	.335	.836**	.343	.291	-.609
Syi	-.838**	1	.944**	.316	.309	.177	-1.000**	.155	.272	.942**
CG	-.613	.944**	1	.609	.602	.468	-.945**	.442	.574	1.000**
CV_{CL}	.243	.316	.609	1	.996**	.872**	-.319	.899**	.984**	.614
CV_{CI}	.247	.309	.602	.996**	1	.863**	-.313	.873**	.978**	.607
DI	.335	.177	.468	.872**	.863**	1	-.179	.790**	.933**	.463
A1	.836**	-1.000**	-.945**	-.319	-.313	-.179	1	-.160	-.275	-.943**
A2	.343	.155	.442	.899**	.873**	.790**	-.160	1	.891**	.449
AI	.291	.272	.574	.984**	.978**	.933**	-.275	.891**	1	.577
TF	-.609	.942**	1.000**	.614	.607	.463	-.943**	.449	.577	1

** Correlation is significant at the 0.01 level (2-tailed).

Section Fuscae

***F. eragrostis* (Nees&Meyen) Hance**

The somatic chromosome of *F. eragrostis* is 2n=10, which is the first examination for the taxon. The species has eight median (m) and two submedian (sm) chromosomes. The shortest chromosome length is 1.86 µm and the longest chromosome longest chromosome is 3.02 µm. The arm ratio ranges from 1.49–2.36 µm (Table 2), while the relative length ranges from 7.96–12.91% (Table 3). The Stebbins category is 3B.

***F. fusca* Benth. ex C.B.Clarke**

The somatic chromosome number is 2n=10, which is new data for the species. *F. fusca* has eight median (m) and two submedian (sm) chromosomes. The shortest chromosome length is 2.19 µm and the longest chromosome length is 2.84 µm. The arm ratio ranges from 1.31–1.90 µm (Table 2), while the relative length ranges from 8.78–11.34%. The Stebbins category is 4B.

Section Miliaceae

***F. littoralis* Gaudich.**

The somatic chromosome number is 2n=10. The result is consistent with Sanyal and Sharma, (1972), but different from Saensouk & Saensouk, (2018) who reported 2n= 20 for the species from Thailand. *F. littoralis* has eight median (m) and two submedian (sm) chromosomes. The shortest

chromosome length is 1.82 µm and the longest chromosome length is 2.15 µm. The arm ratio ranges from 1.17–1.93 µm (Table 2), while the relative length ranges from 9.11–10.77% (Table 3). The Stebbins category is 4A.

***F. umbellaris* (Lam.) Vahl**

The somatic chromosome number for the species is 2n=10, which contrasts with Rath and Patnaik, (1977), who suggested that chromosome number of *F. umbellaris* is 2n= 6. *F. umbellaris* has eight median (m) and two submedian (sm) chromosomes. The shortest chromosome length is 2.18 µm and the longest chromosome length is 2.85 µm. The arm ratio ranges from 1.20–1.82 µm (Table 2), while the relative length ranges from 8.49–11.12% (Table 3). The Stebbins category is 4A.

Section *Pogonostylis*
***F. argentea* (Rottb.) Vahl**

The somatic chromosome number is 2n=20. The species has 14 median (m) and six submedian (sm) chromosomes. The chromosome number is similar to Bir *et al.*, (1992) and Nijalingappa, (1975a). However, Nijalingappa, (1975a) indicated that it has 18 median (m) and two submedian (sm) chromosomes. The shortest chromosome length is 1.38 µm and the longest chromosome length is 2.16 µm. The arm ratio ranges from 1.07–2.76 µm (Table 2), while the relative length ranges from 3.90–6.10% (Table 3). The Stebbins category is 3B.

Section *Trichestylis*
***F. thomsonii* Boeckeler**

The somatic chromosome number is 2n=10, which is the first report for this species. *Fimbristylis thomsonii* has four median (m) and six submedian (sm) chromosomes. The shortest chromosome length is 3.27 µm and the longest chromosome length is 4.05 µm. The arm ratio ranges from 1.22 µm to 2.58 µm (Table 2), while the relative length ranges from 9.20 % to 11.42% (Table 3). The Stebbins category is 3B.

The chromosome counts of *F. eragrostis*, *F. fusca*, *F. insignis*, *F. pubisquama* and *F. thomsonii* are reported here for the first time. The results indicate that the chromosome numbers of the examined *Fimbristylis* taxa are 2n=4 (*F. pubisquama*), 10 (*F. eragrostis*, *F. fusca*, *F. insignis*, *F. littoralis*, *F. ovata*, *F. thomsonii* and *F. umbellaris*), 20 (*F. argentea*) and 26 (*F. dichotoma*). The chromosome counts of *F. argentea*, *F. littoralis* and *F. ovata* conform to Bir *et al.* (1992), Nijalingappa (1975a), Sanyal & Sharma (1972) and Nijalingappa (1975b) respectively, while the chromosome numbers of *F. umbellaris* differ from Rath & Patnaik, (1977) who reported that the chromosome count is 2n=6. In addition, the chromosome number of *F. dichotoma* (2n=26) in the present work differs from those previously published (2n=20 (Sanyal & Sharma, 1972), 2n=10 (Sharma & Bal, 1956), 2n=12 (Hsu, 1972), 2n=32 (Subramanian, 1988) and 2n=28 (Saensouk & Saensouk, 2018). However, *F. dichotoma* may have intraspecific aneuploids, which are common in Cyperaceae (Hoshino *et al.*, 2000). Yano & Hoshino (2006a) examined aneuploidy in Eleocharis kamtschatica (C.A. Mey) Kom. The results revealed that intraspecific aneuploidy in *E. kamtschatica* was common. Moreover, intraspecific aneuploidy within the same population was also found.

The chromosome size varied from 1.01 to 4.87 µm. *Fimbristylis* dichotoma has the shortest chromosomes (1.01 µm) with the highest chromosome count 2n=26, whereas, *F. pubisquama* has the longest chromosomes (4.87 µm) with the lowest number 2n=4. When the chromosome number increases by agmatoploidy (fragmentation), both the lengths and the widths of all chromosomes tend to become smaller (Yano & Hoshino, 2006a). Therefore, *F. dichotoma* may have been derived through fragmentation of the diffuse centromeric chromosome, which has been reported previously in the genus (Yano & Hoshino, 2006b). The smallest arm ratio was observed in *F. dichotoma* (1.00) and the longest arm ratio was examined in *F. argentea* (2.76), whereas, the lowest relative length was determined in *F. dichotoma* (2.70) and the highest relative length was found in *F. pubisquama* (26.42). The centromeric index varied from 26.70 (*F. argentea*) to 49.92 (*F. dichotoma*) in this study. Saensouk & Saensouk (2018) reported that the total length range of *F. dichotoma* and *F. littoralis* are 0.48 to 0.74 µm and 0.76 to 1.24 µm respectively. The centromeric index ranged from 0.52 to 1.00 in *F. dichotoma* and *F. littoralis* is 0.62–1.00, while the arm ratio of *F. dichotoma* is 1.23 to 4.62 and *F. littoralis* is 0.76 to 1.24.

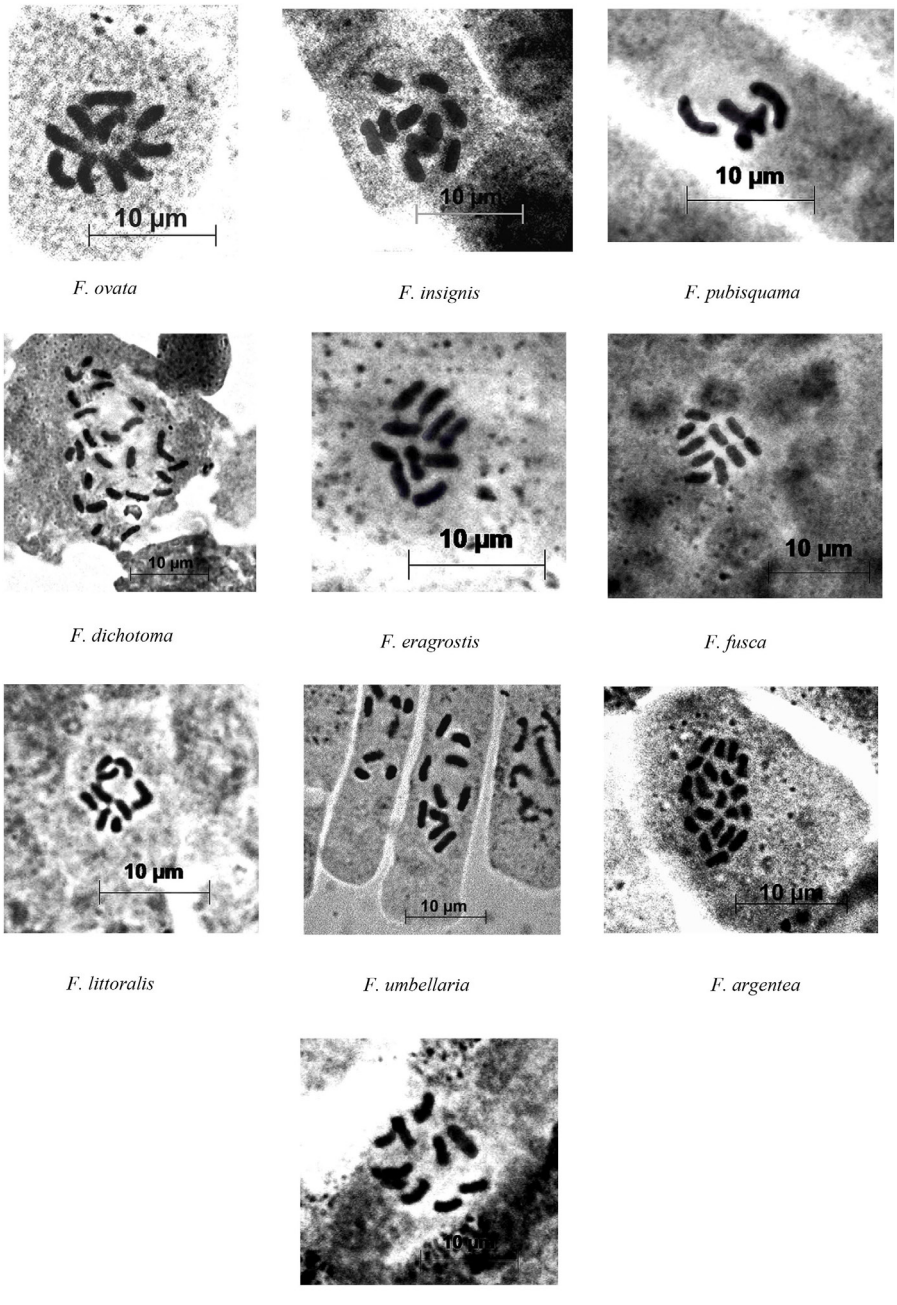

Figure 1. Somatic metaphase chromosomes of *Fimbristylis* taxa.

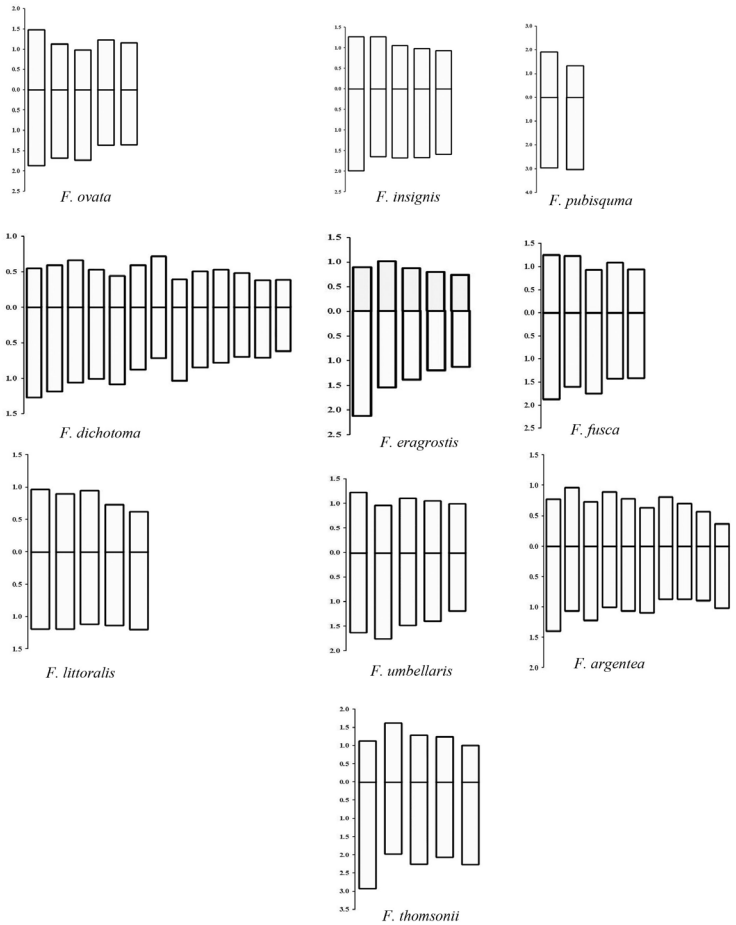

Figure 2. Idiogram of *Fimbristylis* taxa.

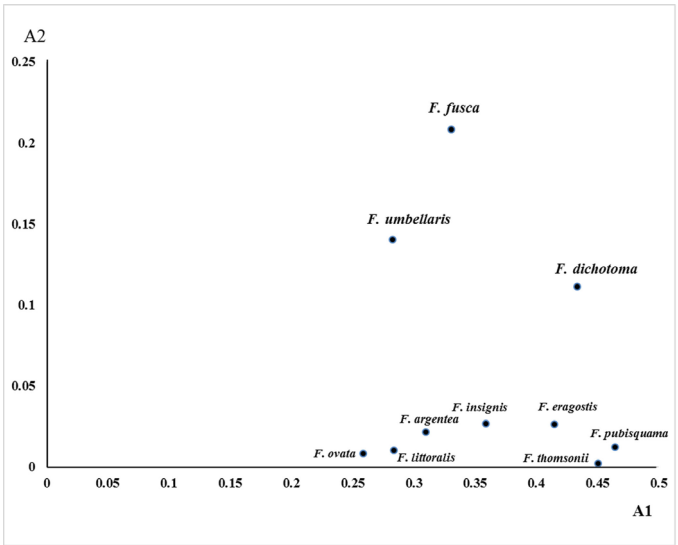

Figure 3. Dispersion diagram of the *Fimbristylis* species studied.

The present study revealed that AsK% varied from 57.45–64.95 and Syi indices ranged from 54.180–74.48, whereas CG values of studied taxa were between 35.064 and 43.442 (Table 3). Also, CV_{CL} values ranged from 0.281–20.809 and CV_{CI} indices varied from 0.549–33.90. Furthermore, the DI indices were between 0.071 and 9.027. The A1 indices were found to be between 0.259 and 0.465, A2 value varied from 0.010–0.208 and AI indices varied from 0.006–7.058. The TF% values varied from 35.102–43.713 in the study. Saensouk & Saensouk (2018) reported that the total percentage (TF%) and Syi indices of *F. dichotoma* were 0.277 and 38.40, and for *F. littoralis* were 0.285 and 40.01. Moreover, the intrachromosomal asymmetry (A1), the interchromosomal asymmetry (A2) and the karyotype asymmetry (AI) of *F. dichotoma* were 0.959, 0.325 and 0.595, and for *F. littoralis* 0.961, 0.222 and 0.425, respectively. Furthermore, the Stebbins classification determination showed that five of the taxa were 3B (*F. argentea*, *F. dichotoma*, *F. eragrostis*, *F. pubisquama* and *F. thomsonii*), three taxa were 4A (*F.littoralis*, *F. ovata* and *F. umbellaris*), while *F. insignis* and *F. fusca* were 4B. Also, Spearman correlation determined among the karyotype features (Table 2) shows that karyotype asymmetry, centromeric gradient (CG), coefficient of variation of chromosome length (CV_{CL}), dispersion index (DI), asymmetry index (A1, A2, AI) and total form percent (TF) are positively correlated ($rs \geq 0.80$, $p \leq 0.01$). The highest positive correlation was observed between the TF and CG indices (1.00). The CV_{CL} did not have any significant correlations with A1 and TF (Table 2). However, A2, AI, DI and CV_{CI} had significant positive correlations with CV_{CL}. Relatively larger and smaller genomes were associated with higher and lower A2 values, respectively (Saha *et al.*, 2014). The AI was positively correlated with A2 but not with A1. In addition, AI was positively correlated with CV_{CL}, indicating that variation in chromosome lengths between chromosomes contributed to karyotype asymmetry (Saha *et al.*, 2014). Figure 3 shows the relationships between two major asymmetry indices. The highest A1 and A2 values were observed in *F. pubisquama* and *F. fusca*, respectively. *F. fusca* and *F. thomsonii* had a highest and lowest AI. Therefore, the highest values of the AI index are considered to indicate higher levels of karyotypicheterogeneity (Poszko, 2006). Base on all asymmetry measurements, *F. fusca* had the most asymmetrical karyotype, while *F. thomsonii* showed the most symmetrical karyotype.

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