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Taxonomic Revision of the *Arisaema undulatifolium* Group (Araceae)

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The taxonomy of members in the *Arisaema undulatifolium* group is revised based on the comparison of eleven morphological traits of 1303 plants from 33 populations. Based on the mean values of six morphological traits for each population, six groups were recognized by cluster analysis. Significant differences among these six groups were found in number of leaflets, width of leaflet, width/length ratio of leaflet, length ratio of peduncle/petiole, auricle size, purple pigmentation and number of ovules per ovary. Five groups recognized by cluster analysis correspond to the existing species, *A. aequinoctiale, A. limbatum, A. minus, A. nambae* and *A. undulatifolium.* The sixth group is newly described as *A. undulatifolium* Nakai subsp. *uwajimense* T. Kobayashi *et* J. Murata, which is distinguished from subsp. *undulatifolium* by the higher width/length ratio of leaflet, the longer peduncle and the more numerous ovules per ovary. *Arisaema limbatum* var. *stenophyllum* and *A. undulatifolium* var. *yosinagae* and *A. limbatum* var. *aequinoctiale* in the sense of Serizawa in J. Jap. Bot. 55, 148-156 (1980) could not be distinguished from each other by any morphological traits examined, and they are thus regarded as a single entity, *A. aequinoctiale. Arisaema limbatum* var. *conspicuum* and *A. limbatum* var. *limbatum* could not be distinguished from each other.

Key words: Araceae, *Arisaema, Arisaema undulatifolium* group, *Arisaema undulatifolium* subsp. *uwajimense*, cluster analysis, nested ANOVA

The *Arisaema undulatifolium* group is commonly characterized by the relatively early flowering season (typically one week to one month earlier than other sympatric *Arisaema* species), the spathe opening before the extension of leaves, the short rachises between leaflets, and the relatively short pseudostem (Serizawa 1980) and is characterized by the highest number of ovules per ovary within the section *Pedatisecta* (Murata 1986). Table 1 shows the comparison of taxa circumscribed by Serizawa (1980) and Murata (1986) in the *A. undulatifolium* group. Serizawa (1980) recognized the *A. undulatifolium* group consisting of nine taxa attributed to four species, but did not refer to *A. nambae* Kitam. Ohashi & Murata (1980) and Ohashi (1986) recognized the *A. undulatifolium* group as a single polymorphic species, *A. undulatifolium* Nakai, incorporating subsp. *nambae* (Kitam.) Ohashi *et* J. Murata and var. *limbatum* (F. Maekawa) Ohashi. Ohashi & Murata (1980) treated *A. kishidae* Makino *ex* Nakai as a distinct species, however, they did not mention its relationship to the *A. undulatifolium* group. Murata (1986) revised this group on the basis of variation pattern of the ratio of peduncle length and petiole length, and the number of ovules per ovary. He excluded *A. kishidae* from the *A. undulatifolium* group and included *A. kishidae* var. *minus* Serizawa as a distinct species, *A. minus* (Serizawa) J. Murata. Watanabe *et al.* (1998) revealed that most of members of the *A. undulatifolium* group in the sense of Murata (1986) had the chromosome number $2n$=26, whereas *A. nambae* and *A. kawashimae* Serizawa had $2n$=28 and considered that the group with $2n$=26 was a cytologically derived group within the sect. *Pedatisecta*. Since Murata's (1986) paper, the circumscription of the *A. undulatifolium* group has become generally accepted, but the polymorphic nature of this group means that the circumscription of each taxon is still unclear.

Kobayashi *et al.* (2000) carried out morphological analysis based on number of leaflets and length ratio of peduncle/petiole for ten populations of the *A. undulatifolium* group in western Japan and recognized four distinct entities, *i. e., A. limbatum* Nakai *et* F. Maekawa *ex* F. Maekawa, *A. minus, A. nambae* and *A. yosinagae* Nakai. However, in order to discuss the taxonomic status of all members of this group, analysis for populations covering the entire distribution range of this group is necessary.

This study aims to examine the variations in morphological traits throughout the distribution range of the *A. undulatifolium* group, using statistical analyses and thereby definitively circumscribe the group's taxa.

Materials and Methods

The geographical distributions of eight taxa and 33 populations attributed to the *Arisaema undulati-*

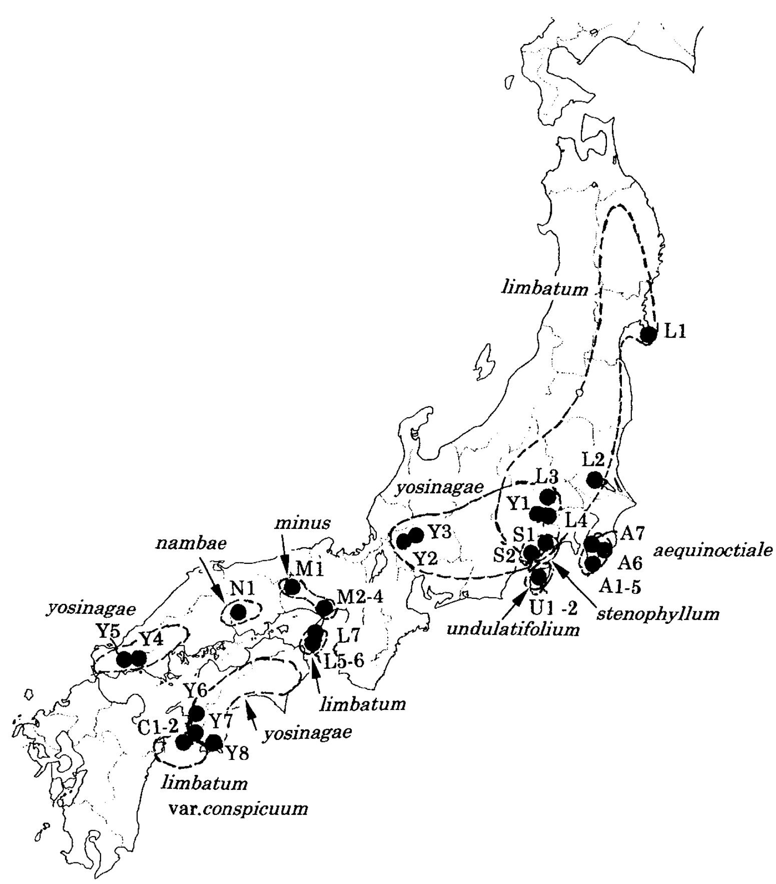

FIG. 1. Geographical distribution of eight taxa and 33 populations examined (●) in the *Arisaema undulatifolium* group.

folium group are shown in Fig. 1. The ninth taxon included in this group by Serizawa (1980), *A. kawashimae* isolated in Tokunoshima Isl. (Kagoshima Prefecture), could not be examined due to probable extinction. The populations examined were selected so as to cover the whole geographical range (from Tohoku District to Shikoku District) of this group and morphological data were obtained from as many individuals as possible in populations. The localities of 33 populations and number of male and female specimens examined are listed in Table 2, where the taxonomic names for *A. limbatum, A. undulatifolium* Nakai, and their varieties used by Serizawa (1980) are indicated because they are more narrowly defined than those of Murata (1986) (Table 1). Voucher specimens are listed in the appendix. Additional specimens housed in the following herbaria were also examined for this taxonomic revision: Aichi University of Education (AICH), KYO, MAK, Natural Museum of Gifu Prefecture, OSA, Shouei Junior College (SHO), TI and TNS (see the appendix).

Number of leaflets, length of leaflet, width of leaflet, length of petiole, length of peduncle, length of pseudo-stem, auricle size at the mouth of spathe and spathe color were examined for a total of 1303 plants (952 males and 351 females). Size of plant parts was measured in the field using a scale to the nearest 1 mm. In this study, "peduncle" means the exposed part of the flowering stem above the pseudo-stem. Measurements of these morphological traits were carried out from early April to mid May, when the spathe and leaf blade are sufficiently extended. For populations C1 and C2, length of leaflet and width of leaflet were measured on herbarium specimens. Auricle size at the mouth of the spathe could not be measured correctly in the field due to its three dimensional form. Thus the auricle size of plant in natural population was estimated by using regression equation for each population at a given peduncle length, because these two variables (peduncle length and auricle size) were significantly correlated (correlation coefficients were 0.615 ($p< 0.01$, n=20) for populations Y1 and Y2, and 0.422-0.666 ($p<0.05$, n=12-27) for the other populations). Purple pigmentation in the spathe of each plant was estimated as a score from 0 to 1.2 with intervals of 0.2 based on field observation. Number of ovules per ovary was counted using a stereoscope for 20 ovaries in a few adjacent series in infructescence. A pool of the counts of ovule number for 86 females from eight populations in our previous works (Murata 1986 and Kobayashi *et al.* 2000) and of 92 females from 18 populations in the present study were used for this analysis.

Cluster analysis was carried out using STA-

TABLE 1. Taxa in the *Arisaema undulatifolium* group circumscribed by Murata (1986), Serizawa (1980) and the present study

Murata (1986)	Serizawa (1980)	Present study	
		Populations	Taxa revised
A. minus	*A. kishidae* var. *minus*	M1-M4	*A. minus*
A. undulatifolium subsp. *nambae*	not mentioned	N1	*A. nambae*
A. undulatifolium subsp. *undulatifolium*	*A. undulatifolium* var. *undulatifolium*	U1-U2	*A. undulatifolium* subsp. *undulatifolium*
	A. undulatifolium var. *yosinagae*	Y6-Y8	*A. undulatifolium* subsp. *uwajimense*
		Y1-Y5	*A. aequinoctiale*
	A. limbatum var. *aequinoctiale*	A1-A7	
	A. limbatum var. *stenophyllum*	S1-S2	
A. undulatifolium var. *limbatum*	*A. limbatum* var. *limbatum*	L1-L7	*A. limbatum*
	A. limbatum var. *conspicuum*	C1-C2	
not mentioned	*A. kawashimae*		not examined
excluded	*A. kishidae*		excluded

TABLE 2. Taxon, locality and altidude of 33 populations, and number of male and female in the *Arisaema undulatifolium* group

Taxon	Population	Locality	Altitude (m)	Number of plants examined		
				Male	Female	Total
nambae	N1	Okayama Pref., Niimi-city	200-300	37	13	50
	M1	Hyogo Pref., Nanko-cho	500-600	22	4	26
minus	M2	Hyogo Pref., Kobe, Kita-ku	200-300	42	26	68
	M3	Hyogo Pref., Kobe, Nishi-ku	100-200	23	3	26
	M4	Hyogo Pref., Kobe, Suma-ku	100-300	37	3	40
	L1	Miyagi Pref., Ojika-cho	50-150	46	17	63
	L2	Ibaragi Pref., Makabe-cho	400-500	55	7	62
limbatum	L3	Saitama Pref., Chichibu-city	400-500	36	27	63
var. *limbatum*	L4	Tokyo Met., Akiruno-city	300-700	10	5	15
	L5	Hyogo Pref., Mihara-cho	150-300	30	13	43
	L6	Hyogo Pref., Mihara-cho	150-300	40	23	63
	L7	Hyogo Pref., Goshiki-cho	200-300	9	0	9
limbatum	C1	Ehime Pref., Nishiumi-cho	50-100	13	12	25
var. *conspicuum*	C2	Kochi Pref., Sukumo-city	50-100	14	5	19
	A1	Chiba Pref., Chikura-cho	100-200	28	2	30
	A2	Chiba Pref., Shirahama-cho	100-200	16	14	30
limbatum	A3	Chiba Pref., Shirahama-cho	100-200	43	17	60
var. *aequinoctiale*	A4	Chiba Pref., Maruyama-cho	50-100	39	7	46
	A5	Chiba Pref., Kimizu-city	200-300	34	10	44
	A6	Chiba Pref., Amatukominato-cho	100-200	33	11	44
	A7	Chiba Pref., Kyonan-cho	50-100	50	11	61
limbatum	S1	Kanagawa Pref., Hakone-cho	1200-1400	27	6	33
var. *stenophyllum*	S2	Shizuoka Pref., Susono-city	1000-1500	41	20	61
	Y1	Tokyo Met., Okutama-cho	800-1200	17	5	22
	Y2	Gifu Pref., Neo-mura	200-300	42	3	45
	Y3	Gifu Pref., Mino-city	600-700	4	0	4
	Y4	Yamaguchi Pref., Tokuchi-cho	400-500	4	0	4
undulatifolium	Y5	Yamaguchi Pref., Yamaguchi-city	100-200	6	0	6
var. *yosinagae*	Y6-'00	Ehime Pref., Uwajima-city	350-700	48	18	66
	Y6-'02	Ehime Pref., Uwajima-city	350-400	32	31	63
	Y7-'95	Ehime Pref., Johen-cho	100-200	20	26	46
	Y7-'02	Ehime Pref., Johen-cho	100-200	31	8	39
	Y8	Kochi Pref., Tosashimizu-city	600-660	6	0	6
undulatifolium	U1	Shizuoka Pref., Amagiyugashima-cho	600-800	15	4	19
var. *undulatifolium*	U2	Shizuoka Pref., Amagiyugashima-cho	600-700	2	0	2
			Total	952	351	1303

Monitoring for populations Y6 and Y7 were carried out in 2000, 2002, 1995 and 2002, respectively.

TISCA 1998 edition (StatSoft Japan), for 26 populations using the following six standardized variables for each population; number of leaflets, length ratio of peduncle/petiole, width/length ratio of leaflet, auricle size at the mouth of spathe, purple pigmentation of spathe for male and female plants, respectively, and number of ovules per ovary. Since there was no significant difference in the length of leaflet, width of leaflet, length of petiole, length of peduncle and length of pseudo-stem among taxa in western Japan (Kobayashi *et al.* 2000), these variables were excluded from this analysis. Five clustering methods, namely, group average method (unweighted pair-group arithmetic average clustering method = UPGMA), furthest neighbor method, Ward method, nearest neighbor method and Centroid method were tested to find the suitable methods to discriminate two distinct taxa (populations N1 and M1-M4 by Kobayashi *et al.* 2000) and UPGMA and furthest neighbor method were selected for this analysis by using the relative Euclidean distance (Euclidean distance$(x, y) = [\sum_i (x_i - y_i)^2]^{1/2}$, each linked Euclidean distance ×100/ the maximum Euclidean distance between clusters). Seven populations were excluded from cluster analysis, because their female numbers examined were less than three. Differences among populations and among taxa for each morphological trait were tested using the nested analysis of variance (the nested ANOVA). Multiple comparisons (the Tukey compromise method: This method is essentially an average of the Tukey honestly significant difference method and the Student-Newman-Keuls method to avoid errors of the latter two methods) among taxa were carried out when taxa's influence in the nested ANOVA were significant ($p<0.05$). The nested ANOVA and the Tukey compromise were carried out using Super ANOVA ver. 1.11 (Abacus Concepts. Inc. U. S. A.).

Results and Discussion

Measurements

Table 3a and 3b show mean value and standard deviation of measurements of eleven morphological traits for male and female plants, respectively.

1) Number of leaflets

Mean number of leaflets ranged from 5.2 (population N1) to 12.1 (population U1) for male and from 6.0 (population N1) to 14.8 (population U1) for female. Mean number of leaflets in populations Y6-Y8 was clearly different from that in populations Y1-Y5 and followed to the highest in populations U1-U2. The female/male ratio in the number of leaflets among populations ranged from 1.07 (population C2) to 1.38 (population M3).

2) Length of leaflet

Mean length of leaflet ranged from 5.8 mm (population Y3) to 19.8 mm (population Y5) for male and from 11.3 mm (population M3) to 20.0 mm (population L5) for female. The female/male ratio in the length of leaflet among populations ranged from 0.81 (population M3) to 1.72 (population Y2).

3) Width of leaflet

Mean width of leaflet ranged from 1.1 mm (population U2) to 6.4 mm (population N1) for male and from 2.2 mm (population U1) to 8.5 mm (population N1) for female. The female/male ratio in the width of leaflet among populations ranged from 1.00 (population M3) to 2.71 (population Y2).

4) Width/length ratio of leaflet

The width/length ratio of leaflet ranged from 0.11 (population U2) to 0.39 (population N1) for male and from 0.15 (population U1) to 0.49 (population N1) for female. The width/length ratios of leaflet for males in populations S1-S2, Y6-Y8 and U1 were clearly lower than that in the remaining populations. The female/male ratio in the width/length ratio of leaflet among populations ranged from 0.96 (population C2) to 1.51 (population Y2).

5) Length of petiole

Mean length of petiole ranged from 4.5 cm (population Y3) to 15.3 cm (population Y5) for male and from 5.5 cm (population Y1) to 11.5 cm (population L5) for female. The female/male ratio in the length of petiole among populations ranged from 0.73 (population M4) to 1.27 (population A7). The petiole scarcely enlarged longitudinally at gender change from male to female.

6) Length of peduncle

TABLE 3a. Mean and standard deviation of ten morphological traits for male of 33 populations in the *Arisaema undulatifolium* group

Taxon	Population	Number of males examined	Number of leaflets	Length of leaflet (mm)	Width of leaflet (mm)	Width/Length ratio of leaflet	Length of petiole (cm)	Length of peduncle (cm)	Length ratio of peduncle/petiole	Length of pseudo-stem (cm)	Auricle size (mm)	Purple pigmentation
nambae	N1	37	5.2±0.8	16.7±3.4	6.4±1.2	0.39±0.01	10.9±2.3	7.0±2.5	0.65±0.20	13.6±5.9	1.2±0.3	1.1±0.0
minus	M1	22	5.9±1.3	8.2±3.5	2.9±1.3	0.36±0.07	6.9±2.0	6.0±1.8	0.88±0.15	7.9±3.0	1.0±0.2	0.2±0.0
	M2	42	6.3±1.2	14.7±4.5	4.8±1.6	0.33±0.05	9.9±2.5	8.6±2.6	0.88±0.32	12.8±7.3	1.2±0.2	0.2±0.0
	M3	23	6.0±1.1	14.0±2.5	4.6±0.7	0.33±0.01	9.1±1.7	7.5±1.9	0.83±0.16	13.6±6.0	1.2±0.2	0.2±0.0
	M4	37	5.7±1.0	13.9±3.4	4.6±1.0	0.33±0.01	9.0±2.4	7.0±2.1	0.78±0.19	12.2±6.3	1.2±0.2	0.2±0.0
limbatum var.*limbatum*	L1	46	8.0±1.2	9.2±2.5	3.2±1.2	0.35±0.06	6.1±1.1	9.6±2.4	1.61±0.44	12.6±5.5	11.2±1.3	1.2±0.2
	L2	55	8.4±1.3	12.6±3.5	4.0±1.4	0.31±0.05	7.8±1.5	10.3±2.8	1.33±0.35	16.2±7.1	9.7±1.0	1.1±0.1
	L3	36	7.5±1.3	15.2±3.2	5.8±1.9	0.38±0.08	8.1±1.2	7.1±2.3	0.89±0.29	11.2±4.8	8.5±0.8	1.1±0.1
	L4	10	7.2±1.1	10.9±2.3	3.5±0.9	0.32±0.06	7.7±0.8	8.2±1.7	1.08±0.24	14.9±5.6	8.9±0.6	1.1±0.1
	L5	30	7.0±1.0	15.5±2.8	4.1±0.9	0.27±0.01	9.7±2.5	8.3±2.3	0.90±0.31	13.0±5.2	9.0±0.8	1.0±0.1
	L6	40	7.7±1.3	13.7±3.4	3.6±1.3	0.26±0.05	8.6±2.3	7.0±2.0	0.85±0.27	9.7±5.1	8.5±0.7	1.0±0.1
	L7	9	7.9±1.1	14.6±5.5	3.9±1.7	0.26±0.04	9.9±4.4	8.7±1.9	0.98±0.36	15.8±5.2	9.1±0.6	1.0±0.1
limbatum var.*conspicuum*	C1	13	8.9±1.3	10.7±2.9	2.9±1.0	0.27±0.02	7.3±2.3	8.5±2.3	1.22±0.27	9.2±3.2	12.8±1.4	1.2±0.1
	C2	13	8.4±1.0	14.9±2.9	4.3±1.0	0.29±0.01	10.5±2.3	8.8±1.8	0.85±0.14	18.2±7.0	12.9±1.1	1.2±0.1
limbatum var.*aequinoctiale*	A1	27	7.9±1.2	18.7±4.1	5.9±1.4	0.32±0.05	13.3±1.7	15.2±4.4	1.16±0.36	29.7±6.2	5.5±0.7	1.0±0.1
	A2	16	8.4±1.1	12.6±3.6	3.5±1.0	0.28±0.04	9.6±1.9	15.6±2.3	1.67±0.38	27.3±6.6	5.5±0.3	1.0±0.1
	A3	43	8.8±1.5	12.5±3.0	3.9±1.2	0.31±0.05	10.3±2.0	15.8±4.3	1.54±0.37	29.3±8.4	5.5±0.6	1.0±0.2
	A4	39	7.9±1.4	11.1±3.2	3.1±1.2	0.28±0.05	9.0±1.7	15.4±3.8	1.75±0.44	21.1±9.9	5.5±0.6	1.0±0.1
	A5	30	7.9±1.4	11.0±2.8	2.9±1.0	0.27±0.05	7.5±1.4	13.1±4.0	1.79±0.59	15.5±6.0	5.1±0.6	1.0±0.2
	A6	29	8.4±1.4	11.9±3.5	3.1±1.4	0.25±0.05	8.4±2.0	14.2±5.1	1.75±0.62	20.7±9.4	5.3±0.7	1.0±0.0
	A7	50	8.1±1.1	13.3±3.1	3.9±1.2	0.29±0.06	8.6±2.0	15.6±3.8	1.86±0.42	19.7±7.1	5.5±0.6	1.0±0.1
limbatum var.*stenophyllum*	S1	27	9.0±1.4	10.0±2.7	2.1±0.7	0.21±0.04	7.3±1.7	8.3±2.2	1.20±0.43	15.3±6.5	5.7±0.4	1.0±0.0
	S2	41	8.4±1.0	10.3±3.0	2.3±0.8	0.22±0.04	8.3±2.5	8.3±2.8	1.07±0.42	15.3±6.0	5.8±0.5	1.0±0.2
undulatifolium var.*yosinagae*	Y1	16	7.8±1.0	9.0±2.1	2.6±0.8	0.28±0.05	6.4±1.1	6.2±1.5	1.00±0.30	8.1±3.6	1.1±0.2	1.0±0.0
	Y2	36	6.9±1.2	7.3±2.5	2.1±0.8	0.29±0.04	7.1±1.9	10.7±3.2	1.55±0.44	12.7±6.6	1.6±0.4	1.0±0.0
	Y3	4	7.0±0.0	5.8±0.9	1.6±0.3	0.27±0.01	4.5±1.3	9.8±1.4	2.26±0.62	13.9±4.7	1.5±0.1	1.0±0.0
	Y4	4	7.5±1.0	13.4±2.1	4.3±0.9	0.32±0.09	9.3±2.7	15.4±4.9	1.70±0.64	25.4±8.3	2.1±0.5	1.0±0.0
	Y5	6	7.8±1.0	19.8±5.7	7.4±3.8	0.36±0.09	15.3±2.5	16.7±3.6	1.11±0.26	30.8±7.7	2.2±0.4	1.0±0.0
	Y6-'00	48	11.2±1.9	8.7±1.2	2.1±0.4	0.23±0.01	6.0±1.6	13.2±3.5	2.30±0.71	12.4±6.0	5.2±0.5	1.0±0.0
	Y6-'02	32	10.5±2.2	13.7±3.1	2.6±1.1	0.19±0.04	6.3±1.7	10.6±2.7	1.80±0.59	12.7±5.0	4.8±0.4	1.0±0.1
	Y7-'95	20	10.9±1.8	10.2±1.2	2.1±0.3	0.21±0.01	7.9±1.5	13.1±3.3	1.69±0.44	18.1±5.8	5.1±0.5	1.0±0.4
	Y7-'02	31	10.5±1.8	18.3±3.2	4.4±1.3	0.24±0.05	7.9±1.6	13.8±2.8	1.77±0.39	16.8±6.0	5.8±0.6	1.0±0.1
	Y8	6	9.0±1.3	16.0±4.1	3.0±1.0	0.18±0.03	7.3±1.2	12.7±3.7	1.80±0.66	18.7±8.6	5.1±0.5	1.0±0.1
undulatifolium var.*undulatifolium*	U1	15	12.1±1.8	10.1±3.6	1.3±0.7	0.12±0.04	7.4±3.4	8.0±2.4	1.23±0.46	11.5±7.4	1.3±0.3	1.0±0.1
	U2	2	12.0	10.2	1.1	0.11	5.8	11.3	1.97	11.3	-	-

Monitoring for populations Y6 and Y7 were carried out in 2000, 2002, 1995 and 2002, respectively. ±standard deviation

Mean length of peduncle ranged from 6.0 cm (populations M1) to 16.7 cm (population Y5) for male and from 7.8 cm (populations M1) to 28.9 cm (population A7) for female. The female/male ratio in the length of peduncle among populations ranged from 1.15 (population M3) to 2.83 (population N1).

7) Length ratio of peduncle/petiole

The length ratio of peduncle/petiole ranged from 0.65 (population N1) to 2.30 (population Y6) for male, and from 1.12 (population M1) to 2.81 (population L1) for female. Males in populations N1 and

TABLE 3b. Mean and standard deviation of eleven morphological traits for female of 28 populations in the *Arisaema undulatifolium* group

Taxon	Population	Number of females examined	Number of leaflets	Length of leaflet (mm)	Width of leaflet (mm)	Width/Length ratio of leaflet	Length of petiole (cm)	Length of peduncle (cm)	Length ratio of peduncle /petiole	Length of pseudo-stem (cm)	Auricle size (mm)	Purple pigmentation	Number of ovules per ovary
nambae	N1	13	6.0±1.0	17.3±2.8	8.5±1.3	0.49±0.01	11.3±1.9	19.8±5.5	1.76±0.45	27.3±10.0	2.6±0.6	1.1±0.3	14.7±2.1(6)
	M1	4	7.3±1.1	14.4±2.0	6.2±0.9	0.43±0.06	7.7±0.8	7.8±2.2	1.12±0.12	11.0±3.4	1.3±0.2	0.2±0.0	14.3±2.6(4)
minus	M2	26	7.7±0.9	18.7±5.9	7.2±2.1	0.39±0.01	11.4±3.0	14.1±2.9	1.29±0.35	21.0±5.1	2.0±0.2	0.2±0.0	15.3±2.3(8)
	M3	3	8.3±1.2	11.3±1.8	4.6±0.6	0.41±0.01	7.3±1.5	8.6±2.0	1.20±0.22	27.9±17.3	1.3±0.2	0.2±0.0	13.7±3.0(7)
	M4	3	7.7±1.0	11.5±2.9	4.7±1.0	0.41±0.02	6.6±2.0	8.3±1.8	1.29±0.15	13.3±11.5	1.5±0.3	0.2±0.0	16.4±3.6(8)
	L1	17	9.1±0.7	12.0±2.2	5.3±1.1	0.45±0.06	6.2±0.8	17.2±3.3	2.81±0.58	22.2±6.4	15.2±1.7	1.1±0.1	14.4±0.9(3)
	L2	7	10.4±1.4	14.8±4.1	5.5±1.3	0.38±0.06	7.7±2.0	15.4±3.1	2.11±0.57	23.4±4.6	11.5±1.1	1.1±0.1	12.5±0.5(2)
limbatum	L3	27	9.2±1.4	18.7±3.5	8.1±2.5	0.43±0.09	8.2±1.4	14.5±3.9	1.78±0.41	15.0±6.4	11.2±1.4	1.1±0.1	12.3±2.8(8)
var.*limbatum*	L4	5	9.6±1.0	14.5±2.3	6.0±0.9	0.41±0.04	7.8±1.6	12.5±2.5	1.65±0.32	31.1±3.2	10.5±0.9	1.1±0.1	12.4±1.8(5)
	L5	13	9.4±1.3	20.0±1.8	6.4±0.7	0.32±0.00	11.5±2.2	17.2±9.0	1.45±0.53	28.4±13.2	12.2±3.3	1.0±0.1	15.7±0.7(4)
	L6	23	9.4±1.0	17.3±3.0	5.4±1.3	0.31±0.06	8.7±1.6	12.4±2.6	1.46±0.38	15.9±6.7	10.4±0.9	1.1±0.1	15.3±3.0(5)
limbatum	C1	12	10.1±1.3	14.5±2.9	4.2±0.6	0.30±0.02	7.8±2.1	15.6±3.7	1.92±0.45	17.1±8.1	17.2±2.3	1.2±0.1	16.7±3.0(7)
var.*conspicuum*	C2	6	9.0±1.3	18.1±1.7	5.0±0.3	0.28±0.01	10.4±1.3	11.2±1.4	1.08±0.15	27.1±2.9	14.4±0.8	1.2±0.1	17.2±4.2(5)
	A1	2	9.0	19.1	8.2	0.43	12.1	20.8	1.71	32.0	6.3	1.0	-
	A2	14	9.9±1.0	16.7±3.2	5.7±1.5	0.34±0.07	10.6±2.1	27.8±5.0	2.74±0.71	43.1±9.3	7.3±0.7	1.0±0.1	12.3±0.9(2)
limbatum	A3	17	10.9±1.2	16.0±2.9	6.0±1.3	0.38±0.05	10.5±2.1	26.1±4.6	2.60±0.69	45.2±8.8	7.1±0.7	1.0±0.1	13.4±1.9(3)
var.*aequinoctiale*	A4	7	10.0±1.4	17.2±2.9	6.1±2.3	0.35±0.08	9.3±2.0	24.7±5.4	2.70±0.40	24.7±8.6	6.9±0.8	1.0±0.1	12.3±0.9(2)
	A5	10	8.8±1.2	13.6±2.2	4.8±1.1	0.35±0.04	8.1±2.0	19.0±3.9	2.45±0.57	22.8±6.8	6.0±0.6	1.0±0.1	13.5±2.5(5)
	A6	11	9.7±1.1	16.3±4.3	5.7±2.1	0.34±0.07	9.5±0.9	22.7±5.1	2.41±0.57	28.0±6.4	6.6±0.8	1.0±0.1	13.9±2.7(31)
	A7	11	10.3±1.0	19.0±4.7	7.3±1.4	0.39±0.05	10.9±1.2	28.9±5.6	2.66±0.53	42.3±5.6	7.5±0.8	1.0±0.1	14.3±2.1(5)
limbatum	S1	6	10.0±1.0	13.1±3.2	3.1±1.1	0.24±0.06	7.3±1.8	12.9±2.3	1.84±0.41	24.6±11.1	6.6±0.4	1.0±0.1	10.6±2.1(7)
var.*stenophyllum*	S2	20	9.9±1.3	13.6±2.3	3.3±0.8	0.25±0.05	7.3±1.7	13.8±3.6	1.93±0.43	23.4±9.0	6.7±0.6	1.0±0.1	12.3±1.3(2)
	Y1	5	9.0±1.1	12.1±3.3	4.0±0.9	0.34±0.07	5.5±0.6	12.0±3.9	2.13±0.51	14.0±7.7	1.7±0.4	1.0±0.0	11.0±2.0(2)
	Y2	3	8.7±0.6	13.1±1.6	5.7±0.8	0.43±0.05	8.5±1.8	13.6±2.1	1.59±0.22	21.8±8.1	1.9±0.2	1.0±0.0	17.6±2.1(3)
undulatifolium	Y6-'00	18	14.4±2.6	12.6±1.5	3.7±0.3	0.30±0.01	6.5±1.4	17.2±3.5	2.70±0.44	19.4±7.5	5.7±0.5	1.0±0.1	21.2±4.4(11)
var.*yosinagae*	Y6-'02	31	13.0±1.5	19.7±4.0	5.3±2.0	0.27±0.08	6.8±1.7	17.4±3.9	2.65±0.64	22.0±6.3	5.8±0.6	1.0±0.0	22.5±3.1(14)
	Y7-'95	26	11.8±1.5	14.8±1.6	3.6±0.3	0.25±0.01	8.6±1.6	18.5±4.0	2.18±0.37	23.6±5.9	5.9±0.6	1.1±0.1	20.2±3.3(5)
	Y7-'02	8	11.1±2.2	19.0±2.5	5.7±1.2	0.31±0.07	7.7±2.2	17.1±2.8	2.35±0.60	19.6±5.9	5.7±0.4	1.0±0.1	19.8±4.0(12)
undulatifolium var.*undulatifolium*	U1	4	14.8±1.1	14.6±3.5	2.2±0.4	0.15±0.02	7.7±1.4	10.5±2.6	1.41±0.48	15.6±3.5	1.6±0.3	1.0±0.0	12.1±0.4(2)

Monitoring for populations Y6 and Y7 were carried out in 2000, 2002, 1995 and 2002, respectively. Number of females examined for ovule number per ovary shows in parenthesis. ±standard deviation

M1-M4 were characterized by the length ratio of peduncle/petiole less than 0.9. The female/male ratio in the length ratio of peduncle/petiole among populations ranged from 1.03 (population Y2) to 2.71 (population N1). The peduncle enlarged remarkably in population N1 and the peduncle/petiole ratio changes from 0.65 to 1.76 at gender change from male to female in this population.

8) Length of pseudo-stem

Mean length of the pseudo-stem ranged from 7.9 cm (population M1) to 30.8 cm (population Y5) for male, and from 11.0 cm (population M1) to 45.2 cm (population A3) for female. The female/male ratio in the length of pseudo-stem among populations ranged from 1.09 (population M4) to 2.19 (population L5).

9) Auricle size at the mouth of spathe

Mean length of auricle size at the mouth of spathe ranged from 1.6 mm (population M1) to 12.9 mm (population C2) for male, and from 1.3 mm (population M1) to 17.2 cm (population C1) for female. The female/male ratio in auricle size at the mouth of spathe among populations was ranged from 0.98 (population Y7) to 2.17 (population N1).

Auricle size at the mouth of spathe has been regarded as a key diagnostic character distinguishing *A. limbatum* var. *conspicuum* and var. *limbatum* from the remaining taxa in the *A. undulatifolium* group. It, however, varies largely among the populations of *A. limbatum*. Plants in populations C1-C2 and L1 have larger auricles than those in populations L2-L7. The estimated auricle size was 12.8-17.2 mm (populations C1-C2), and 11.2-15.2 mm (population L1) and 8.5-12.2mm (populations L2-L7). Auricle size in populations N1, M1-M4, Y1-Y5, U1 and U2 (1.0-2.6 mm) was clearly smaller than that of populations A1-A7 (5.1-7.5 mm), S1-S2 (5.7-6.7 mm) and Y6-Y8 (4.8-5.9 mm).

10) Purple pigmentation of spathe

Mean quantity of purple pigment in spathe ranged from 0.2 (populations M1-M4) to 1.2 (populations L1, C2 and C2) both for male and female. The female/male ratio in purple pigmentation of spathe was 1.11 in population A3 and 1.00 in the remaining all populations.

Populations M1-M4 are characterized by the greenish brown and semi-transparent limb of spathe, although the outer part of the spathe tube is tinged with purple. The whole of the spathe is colored with purple pigment in plants from the remaining populations. The spathe color is dark purple in plants from populations L1-L4, C1 and C2, but its color tone varies among populations. Greenish spathe were found in one plant from each of populations A3, A5, A6, M3, N1, L1 and S2, and a greenish brown spathes were found in one plant from each of populations L7 and Y7.

11) Number of ovules per ovary

Murata (1986) examined the number of ovules per ovary extensively in the genus *Arisaema* and defined the *A. undulatifolium* group by the mean number of ovules per ovary greater than 10.5. On the basis of the count of ovule number for five taxa in western Japan (Kobayashi *et al.* 2000) and for seven taxa (92 plants from 18 populations in the present study), the number of ovules per ovary ranged from 10.6 (population S1) to 22.5 (population Y6) in the *A. undulatifolium* group. The number of ovules per ovary tends to be higher in western Japanese populations than in eastern Japanese populations.

Cluster analysis

Two dendrograms for 26 populations obtained by UPGMA and furthest neighbor method are shown in Fig. 2. Topologies of both dendrograms are basically concordant. Three major clusters, *i. e.*, the first cluster including populations N1 and M1-M4, the second cluster including populations L1-L6, C1, C2, A2-A7, S1, S2, Y1 and Y2, and the third cluster including populations U1, Y6 and Y7, were recognized. Each of them was clustered at the relative Euclidean distances 58-89, 54-60 and 48-72, respectively, in these two methods. Within the second cluster, two subclades were recognized, *i. e.*, one subclade consisted of populations L1-L6, C1 and C2, and the other populations A2-A7, S1, S2, Y1 and Y2.

Since populations N1 and M1-M4 correspond to the distinct species, *A. nambae* and *A. minus*, respectively (Kobayashi *et al.* 2000), we set the species or subspecies border at the relative Euclidean distances of 50-60. Then 26 populations in the *A. undulatifolium* group were grouped together into the following six groups as shown in Fig. 2; *i. e.*, Group 1 (population N1), Group 2 (populations M1-M4), Group 3 (populations L1-L6 and C1-C2), Group 4 (populations A2-A7, S1-S2 and Y1-Y2), Group 5 (population U1) and Group 6 (populations Y6-Y7).

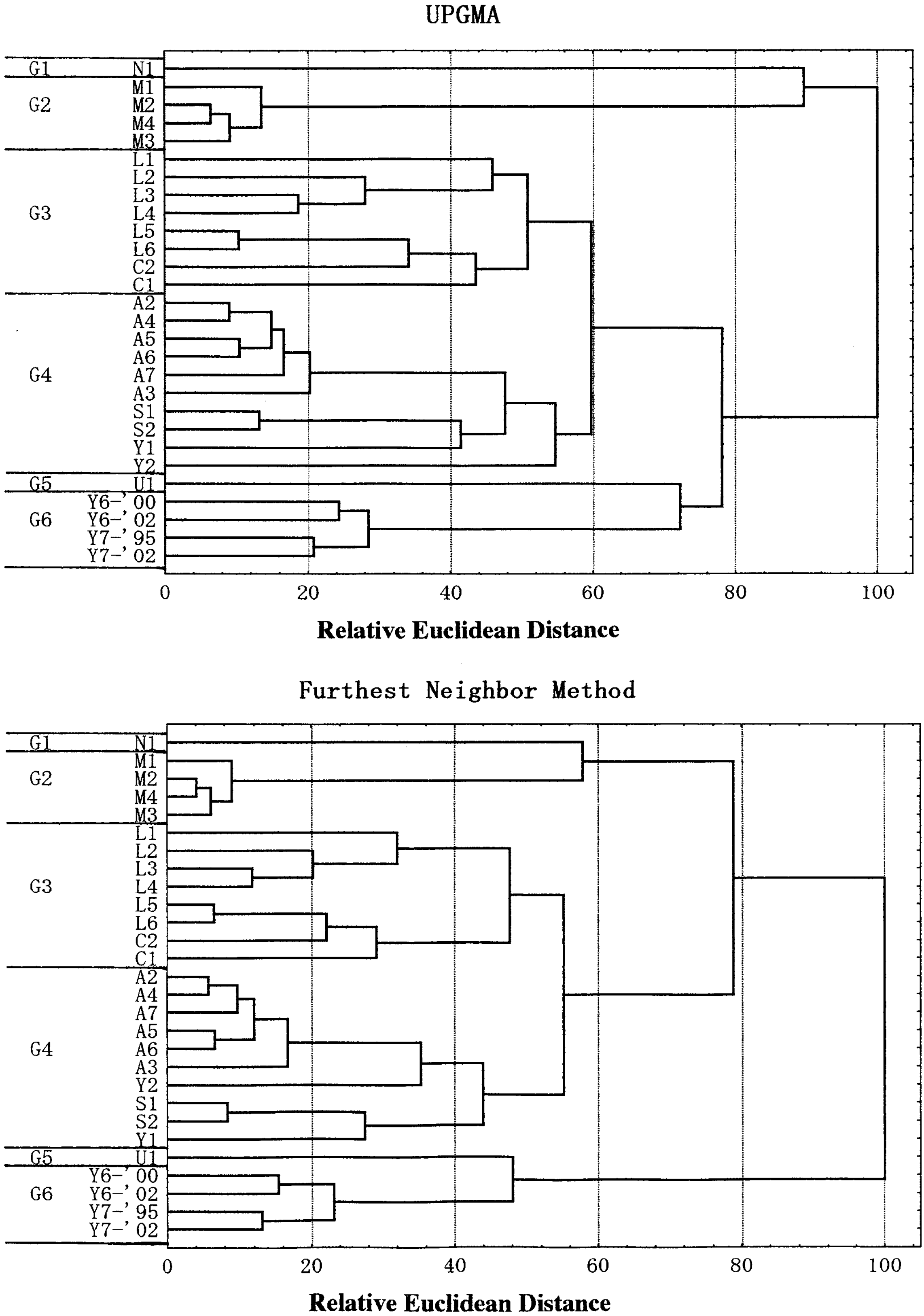

FIG. 2. Dendrograms by cluster analysis based on mean values of six variables for 26 populations in the *Arisaema undulatifolium* group. Dendrograms were obtained by UPGMA (above) and furthest neighbor method (below). Monitoring for populations Y6 and Y7 were carried in 2000, 2002, 1995 and 2002, respectively. Six groups (G1-G6) were recognized by cluster analysis.

Groups 1, 2, 3 and 5 correspond to *A. nambae, A. minus, A. limbatum s. str.* (excluding var. *aequinoctiale* and var. *stenophyllum*) and *A. undulatifolium* var. *undulatifolium*, respectively. Group 4 includes *A. undulatifolium* var. *yosinagae* (populations Y1-Y2), *A. limbatum* var. *aequinoctiale* (populations A2-A7) and *A. limbatum* var. *stenophyllum* (populations S1-S2), and referred to as *A. aequinoctialine* hereafter. Group 6 does not correspond to any taxon and is called tentatively *Arisaema* sp. 1.

The nested ANOVA and the Tukey compromise
Significant differences among populations were found in all measured variables of ten morphological traits, both for male and female, by the nested ANOVA (Table 4). For the number of ovules per ovary, its variation within some populations with many females examined exceeds that among populations with limited number of females examined

TABLE 4. Mean values of eleven morphological traits for six taxa in the *Arisaema undulatifolium* group and results of the nested ANOVA and the Tukey compromise

Male

	nambae	*minus*	*limbatum*	*aequinoctiale*	*undulatifolium*	sp. 1	F-values	
Number of populations	1	4	9	11	1	2	Among	Among
Number of males	37	91	250	370	17	65	populations	taxa
Number of leaflets	5.2^{a}	5.9^{a}	7.9^{b}	8.1^{b}	12.1^{c}	11.1^{c}	4.98***	32.87***
Length of leaflet (mm)	16.7	12.7	12.9	11.5	10.7	9.2	20.84***	1.43
Width of leaflet (mm)	6.4^{b}	4.2^{ab}	4.0^{ab}	3.2^{a}	1.2^{a}	2.1^{a}	20.74***	4.46**
Width/Length ratio of leaflet	0.39^{c}	0.34^{bc}	0.31^{bc}	0.27^{bc}	0.11^{a}	0.23^{b}	18.19***	7.10***
Length of petiole (cm)	10.9	8.2	8.1	8.7	7.2	6.6	19.50***	1.05
Length of peduncle (cm)	7	6.9	8.7	12.9	8.4	13.2	19.19***	4.09**
Length ratio peduncle/petiole	0.65^{a}	0.90^{a}	1.14^{a}	1.52^{ab}	1.32^{a}	2.11^{b}	15.88***	5.30**
Length of pseudo-stem (cm)	13.6	11.6	13.1	19.6	11.9	14.1	17.24***	1.99
Auricle size (mm)	1.2^{a}	1.2^{a}	9.8^{b}	4.8^{a}	1.3^{a}	5.1^{a}	128.43***	20.04***
Purple pigmentation	1.1^{b}	0.2^{a}	1.1^{b}	1.0^{b}	1.0^{b}	1.0^{b}	9.15***	178.86***

Female

	nambae	*minus*	*limbatum*	*aequinoctiale*	*undulatifolium*	sp. 1	F-values	
Number of populations	1	4	8	10	1	2	Among	Among
Number of females	13	17	108	104	4	42	populations	taxa
Number of leaflets	6.0^{a}	7.5^{ab}	9.4^{b}	9.9^{b}	14.8^{c}	12.8^{c}	3.59***	24.21***
Length of leaflet (mm)	17.3	14.7	16.5	15.4	14.6	14	7.04***	0.75
Width of leaflet (mm)	8.5^{b}	5.9^{ab}	6.1^{ab}	5.2^{ab}	2.2^{a}	3.7^{ab}	9.72***	3.14*
Width/Length ratio of leaflet	0.49^{b}	0.41^{b}	0.37^{ab}	0.33^{ab}	0.15^{a}	0.27^{ab}	13.77***	3.79*
Length of petiole (cm)	11.3	9.2	8.4	9	7.7	7.8	9.27***	0.96
Length of peduncle (cm)	19.8	10.9	14.7	21.3	10.5	17.9	11.45***	2.00
Length ratio peduncle/petiole	1.76	1.23	1.86	2.37	1.41	2.38	7.18***	2.82*
Length of pseudo-stem (cm)	27.3	19.4	19.8	32.5	15.6	22	11.52***	1.12
Auricle size (mm)	2.6^{a}	1.6^{a}	12.6^{b}	6.5^{ab}	1.6^{a}	5.9^{a}	26.37***	17.99***
Purple pigmentation	1.1^{b}	0.2^{a}	1.1^{b}	1.0^{b}	1.0^{b}	1.0^{b}	4.70E16***	80.03***
No. ovules per ovary (No.females)	14.7^{a}(6)	15.1^{a}(27)	14.7^{a}(39)	13.1^{a}(21)	12.2^{a}(2)	21.3^{b}(26)	1.58	14.1***

Significant level:***, p<0.001; **,p<0.01;*,p<0.05, a,b,c,d: mean with the same letter in a row are not significantly different at 5 % level by the Tukey compromise.

because of the scarcity. In males, there were significant differences among six taxa in the mean values of number of leaflet, auricle size at the mouth of spathe, purple pigmentation of spathe, length/width ratio of leaflet ($p<0.001$), width of leaflet, length of peduncle and length ratio of peduncle/petiole ($p<0.01$). In females, there were significant differences among six taxa in the mean values of number of leaflets, auricle size at the mouth of spathe, purple pigmentation of spathe, number of ovules per ovary ($p<0.001$), width of leaflet, length/width ratio of leaflet and length ratio of peduncle/petiole ($p<0.05$).

Significant differences between taxa were found in the following mean values of six morphological traits for male and female plants, respectively, by the Tukey compromise (Table 4). In males, there were significant differences among three species pairs, namely 1) *A. nambae* and *A. minus*, 2) *A. limbatum* and *A. aequinoctiale*, and 3) *A. undulatifolium* and *A.* sp.1, for the mean values of the number of leaflets. *Arisaema nambae* was distinguished from *A. minus* by purple pigmentation in the spathe both for male and female plants. *Arisaema limbatum* was distinguished from *A. aequinoctiale* by auricle size at the mouth of spathe for male. *Arisaema undulatifolium* was distinguished from *A.* sp. 1 by the width/length ratio of leaflet and the length ratio of peduncle/petiole for male and by the number of ovules per ovary for female plants.

Taxonomic Conclusion

The cluster analysis and the nested ANOVA followed the Tukey compromise recognized six distinct taxa in the *Arisaema undulatifolium* group. They are *A. aequinoctiale, A. limbatum, A. minus, A. nambae, A. undulatifolium* and *Arisaema* sp. 1, respectively. *Arisaema* sp. 1 was clustered with *A. undulatifolium* around the border distance between species and subspecies in the furthest neighbor method. *Arisaema* sp. 1 was distinguished from *A. undulatifolium* by the higher width/length ratio of leaflet, the longer peduncle and the more numerous ovules per ovary (Table 4). Based on these morphological differences and its geographical isolation from other populations of *A. undulatifolium*, we treated it as a new subspecies, *A. undulatifolium* Nakai subsp. *uwajimense* T. Kobayashi *et* J. Murata (subsp. nov., Japanese name: Uwajima-tennansho). The taxonomic status and circumscription of six taxa recognized in the present study are as follows. The new system treatment is compared to those of Murata (1986) and Serizawa (1980) in Table 1.

1) *Arisaema aequinoctiale* Nakai *et* F. Maekawa *ex* F. Maekawa in Bot. Mag. Tokyo 46: 561 (1932)—*A. limbatum* F. Maekawa var. *aequinoctiale* (F. Maekawa) Serizawa in J. Jap. Bot. 55:148 (1980). Type: Japan. Honshu. Chiba Prefecture, Mt. Kiyozumi, *T. Nakai* (TI-Holotype)

A. stenophyllum Nakai *et* F. Maekawa *ex* F. Maekawa in Bot. Mag. Tokyo 46:561(1932)—*A. undulatifolium* Nakai var. *stenophyllum* (Nakai *et* F. Maekawa *ex* F. Maekawa) Sugimoto in Amat. Herb. 16: 36 (1954), non. r. p. —*A. limbatum* Nakai *et* F. Maekawa *ex* F. Maekawa var. *stenophyllum* (Nakai *et* F. Maekawa *ex* F. Maekawa) Serizawa in J. Jap. Bot. 55:148 (1980). Type: Japan. Honshu. Kanagawa Prefecture, Hakone, Mt. Kintoki-yama. June 1930 (Cultivated in Tokyo, 2 May 1931) *K. Hisauti* (TI-Lectotype chosen by Ohashi 1986).

A. yosinagae Nakai in Icon. Pl. As. Orient. 3(1): 199 (1939)—*A. undulatifolium* Nakai var. *yosinagae* (Nakai) Serizawa in J. Jap. Bot. 55:148(1980). Type: Japan. Shikoku. Tokushima Prefecture, Aki-gun, Sakinohama. 31 March 1937, *T. Yosinaga* (TI-Holotype).

Japanese name: Higan-mamushigusa (F. Maekawa 1932)

Chromosome number: $2n = 26$ (Watanabe *et al.* 1998)

Distribution: Honshu (Kanto, Chubu & Chugoku Districts), Shikoku. (populations Y1-Y5,

Key to six taxa in the *Arisaema undulatifolium* group

1. Leaflets 3-9 (less than 7 in mean value) in male and 5-9 (less than 9 in mean value) in female. Length ratio of peduncle/petiole less than 0.9 in mean value in male. Spathe narrowly recurved at the mouth.
  2. Leaflets 3-7 in male and 5-7 in female. Length ratio of peduncle/petiole more than 1.5 in mean value in female. Spathe purplish dark brown to dark purple. Chromosome number $2n$=28.
  Endemic to limestone area in Okayama and Hiroshima Prefectures. .... 4. *A. nambae*
  2. Leaflets 5-7 in male and 6-9 in female. Length ratio of peduncle/petiole less than 1.5 in mean value in female. Spathe greenish brown and the limb semi-transparent. Chromosome number $2n$=26. Endemic to Hyogo Prefecture. .... 3. *A. minus*
1. Leaflets 5-17 (more than 7 in mean value) in male and 7-21 (more than 9 in mean value) in female. Length ratio of peduncle/petiole more than 0.9 in mean value in male. Spathe narrowly to widely recurved at the mouth.
  2. Leaflets 5-13 (less than 9 in mean value) in male and 7-13 (less than 11 in mean value) in female.
    3. Spathe narrowly recurve, or occasionally rather widely recurved at the mouth. Auricle size less than 6 mm in mean value in male and less than 8 mm in mean value in female. Spathe usually purplish dark brown. Occur from Kanto to Chubu Districts and from Chugoku to Shikoku Districts.
    .... 1. *A. aequinoctiale*
  2. Spathe widely recurved at the mouth. Size of auricle more than 8 mm in mean value in male and 10 mm in mean value in female. Spathe purplish dark brown, or occasionally dark purple. Distributed from Tohoku to Kanto Districts, in Hyogo Prefecture (Awaji Isl.) and from western Shikoku District to Oita Prefecture. .... 2. *A. limbatum*
  2. Leaflets 9-17 (more than 9 in mean value) in male and 13-21 (more than 11 in mean value) in female.
    3. Leaflets usually narrow, ratio of width/length 0.11-0.15 in mean value. Endemic to Izu Peninsula. Number of ovules per ovary 11.7-12.6 (less than 13.0 in mean value).
    .... 5a. *A. undulatifolium* subsp. *undulatifolium*
  2. Leaflet slightly narrow, ratio of width/length 0.18-0.31 in mean value. Occur in western Shikoku District. Number of ovules per ovary 13.0-27.6 (more than 19.0 in mean value).
    .... 5b. *A. undulatifolium* subsp. *uwajimense*

S1-S2 and A1-A7 in Fig. 1)

Habitat: Warm to cold temperate forest (alt. 50-1500 m).

We selected *Arisaema aequinoctiale* Nakai *et* F. Maekawa *ex* F. Maekawa (Japanese name: Higan-mamushigusa) for this entity.

2) *Arisaema limbatum* Nakai *et* F. Maekawa *ex* F. Maekawa in Bot. Mag. Tokyo 46: 562(1932) —*A. undulatifolium* Nakai var. *limbatum* (F. Maekawa) Ohashi and forma *limbatum* (F. Maekawa) Ohashi, J. Jpn. Bot. 61: 172 (1986). Type: Japan. Honshu. Tokyo Met. Kariyosedani, Apr. 1931, *F. Maekawa* (TI-Holotype).

A. limbatum var. *ionostemma* Nakai *et* F. Maekawa *ex* F. Maekawa in Bot. Mag. Tokyo 46: 564 (1932). —*A. undulatifolium* Nakai subsp. *undulatifolium* var. *ionostemma* (F. Maekawa) Ohashi *et* J. Murata in J. Fac. Sci. Univ. Tokyo III, 12: 281(1980) Type: Japan. Honshu. Gunma Prefecture, Usui-toge. 8 May 1932, *H. Hara* 844. *e*. (TI-Holotype).

A. limbatum forma *plagiostomum* Nakai in Icon. Pl. As. Orient. 2(2): 116 (1937). Type: Japan. Honshu. Prov. Musashi, Mt. Takaosan, Apr. 1937, *M. Shibata* (TI-Holotype).

A. limbatum forma *angustifolium* Hayashi in Bull. Forest Exp. St. no.125, 76 (1960). Type: Japan. Honshu. Musashi, Mt. Takaosan, 23 Apr. 1958 (TNS-Holotype).

A.limbatum forma *viridiflavum* Hayashi in Hokuriku Journ. Bot. 11(4): 118 (1963) —*A. undulatifolium* Nakai forma *viridiflavum* (Hayashi) Ohashi *et* J. Murata in J. Fac. Sci. Univ. Tokyo III, 12: 309 (1980). Type: Japan. Honshu. Musashi, Mt. Minenoyakushi, 1 Apr. 1962, *K. Mineo* (TNS-Holotype).

A. limbatum Nakai var. *conspicuum* Serizawa in J. Jap. Bot. 55:148 (1980) Type: Japan. Shikoku. Kochi Prefecture, Island Okinoshima. 29 March 1971, *S. Serizawa* 13645 (AICH-Holotype).

Japanese name: Mimigata-tennansho (F. Maekawa 1932)

Chromosome number: $2n$=26 (Watanabe *et al.* 1998)

Distribution: Honshu (Tohoku, Kanto & Kinki Districts), Shikoku, Kyushu (Ooita Prefecture) (populations L1-L7, C1 and C2 in Fig. 1)

Habitat: Warm temperate forest (alt. 50-700 m)

3) *Arisaema minus* (Serizawa) J. Murata in Acta Phytotax. Geobot. 37: 27 (1986) —*A. kishidae* Makino ex Nakai var. *minus* Serizawa in J. Jap. Bot. 55:148 (1980). Type: Japan. Honshu. Hyogo Prefecture, Sayo-gun, Nanko-cho, Mt. Funakoshi-yama, 4 Apr. 1978, *S. Serizawa 27838* (AICH-Holotype)

Japanese name: Harima-mamushigusa (Serizawa 1980)

Chromosome number: $2n$=26 (Watanabe *et al.* 1998)

Distribution: Western Honshu (endemic to Hyogo Prefecture). (populations M1-M4 in Fig. 1)

Habitat: Warm temperate forest, mainly secondary forest (alt. 200-600 m)

4) *Arisaema nambae* Kitam. in Acta Phytotax. Geobot. 22: 65 (1966) —*A. undulatifolium* Nakai subsp. *nambae* (Kitam.) Ohashi *et* J. Murata in J. Fac. Sci. Univ. Tokyo III, 12: 281 (1980). Type: Japan. Honshu. Okayama Prefecture, Takahashi-city, Otemon, Mt. Gagiu-san, 27 Apr. 1954, *S. Nanba* (KYO-Holotype)

Japanese name: Takahashi-tennansho (Kitamura *et al.* 1964)

Chromosome number: $2n$=28 (Watanabe *et al.* 1998)

Distribution: Western Honshu (endemic to the limestone areas of Okayama and Hiroshima Prefectures). (population N1 in Fig. 1)

Habitat: Warm temperate forest (alt. 200-500 m)

Ohashi & Murata (1980) recognized *A. nambae* as a subspecies of *A. undulatifolium*. *Arisaema nambae*, however, was clearly distinguished from *A. undulatifolium* and rather resembled *A. minus* in many morphological traits, except for spathe color, chromosome number and distribution range as shown in this study. *Arisaema nambae* is distinct in the differentiation of the length ratio of peduncle/petiole between female and male and the chromosome number ($2n$=28) in the *A. undulatifolium* group.

5) *Arisaema undulatifolium* Nakai in Bot. Mag. Tokyo 43: 539 (1929). Type: Japan. Honshu. Shizuoka Prefecture, Mt. Amagi. April 1928, *M. Ogata* (TI-Holotype).

5a) subsp. *undulatifolium*

A. undulatifolium Nakai forma *serrulatum* Nakai in Icon. Pl. As. Orient. 3: 194 (1939). Type: Japan. Honshu. Shizuoka Prefecture, around Zyoren no-taki, Apr. 1930, T. Nakai.

A. undulatifolium Nakai forma *viridifolium* Sugimoto, non r. p. in Fl. Shizuoka 487 (1967). Type: Japan, Honshu. Shizuoka Pref., Mt. Amagi, *J.*

Sugimoto (Holotype not traced).

Japanese name: Nagaba-mamushigusa (F. Maekawa 1932)

Chromosome number: 2*n*=26 (Watanabe *et al* .1998)

Distribution: Eastern Honshu (Shizuoka Prefecture, endemic to the Izu Peninsula). (populations U1 and U2 in Fig. 1)

Habitat: Warm to cold temperate forest (alt. 600-1000 m).

5b) subsp. **uwajimense** T. Kobayashi *et* J. Murata, **subsp. nov.**

Differt a typi subspecie peduculo longioribus, ovulis multioribus.

Type: Shikoku. Ehime Prefecture, Uwajima-city, Nametoko valley, 12 Apr. 2000, *T. Kobayashi 34223* (KYO-Holotype).

Leaves usually 2; peduncle 5-30 cm long; petiole 3-15 cm long; leaf blade pedately dissected; leaflets 7-21 and frequently white-variegated along midvein, 8-27 cm long, 1-11 cm wide (width/length ratio 0.11-0.46), rachis between leaflets shortly developed. Peduncle distinctly (more than two times in female) longer than petiole. Inflorescence preceding to leaves; spathe purplish dark brown, moderately auricled at the mouth. Number of ovules per ovary more than 20 in average.

Japanese name: Uwajima-tennansho

Chromosome number: 2*n*=26 (as *Arisaema yosinagae*; Watanabe *et al.* 1998)

Distribution: Southwestern Shikoku (Ehime and Kochi Prefectures) (populations Y6-Y8 in Fig. 1): Ehime Prefecture, Uwajima-city, Nametoko valley (*T. Kobayashi 34219-34222, 36846-36849, T. Kobayashi 34223*- Holotype in KYO), Minamiuwa-gun, Johenn-cho, Souzu (*S. Serizawa 29065-29069, 36525-36533* AICH, *T. Kobayashi.26837, 26838* SHO), Kochi Prefecture, Tosashimizu-city, Mt. Imanoyama (*T. Kobayashi 36850-36852* SHO)

Habitat: Warm temperate forest (alt. 100-700 m).

Arisaema undulatifolium subsp. *undulatifolium* and subsp. *uwajimense* are characterized by the narrowest and the most numerous leaflets in the *A. undulatifolium* group, respectively.

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Appendix

Voucher specimens and specimens examined in herbarium (AICH, KYO, MAK, Natural Museum of Gifu Prefecture, OSA, SHO, TI and TNS) for six taxa of the *Arisaema undulatifolium* group in Japan are as follows.

1) *Arisaema aequinoctiale* Nakai et F. Maekawa ex F. Maekawa (Higan-mamushigusa)

(Voucher specimens)

Chiba Prefecture. Kominato-cho, Sakamoto (population A6, *T. Kobayashi 35631* SHO), Shirahama-cho (populations A2 and A3, *T. Kobayashi 34243-34258* SHO, KYO, OSA), Chikura-cho, Mt. Takatsuka (population A1, *T. Kobayashi 5636* SHO), Kyonan-cho, Okuyama (population A7, *T. Kobayashi 35641-35643* SHO), Maruyama-cho, Kawatani (population A4, *T. Kobayashi 35637-35640* SHO), Kimizu-city, Mt. Mitsuishi (population A5, *T. Kobayashi 35632-35635* SHO), **Kanagawa Prefecture.** Hakone-cho, Mt. Kamiyama (population S1, *T. Kobayashi 35967-35978* SHO), **Shizuoka Prefecture.** Fuji-city, Mt. Echizendake (population S2, *T. Kobayashi 35929-35941* SHO), **Tokyo Met.** Okutama-cho, Ogawa-dani (population Y1, *T. Kobayashi 35718-35722* SHO), **Gifu Prefecture.** Mino-city, Mt. Hyougatake (population Y3, *T. Kobayashi 35680-35686* SHO), Neo-mura, Midori-dani (population Y2, *T. Kobayashi 35675-35682* SHO), **Yamaguchi Prefecture.** Tokuchi-cho, Mitani (population Y4, *T. Kobayashi 30238, 30355, 30358* SHO)

(Specimens examined)

Ibaragi Prefecture. Tsukuba-city, Mt. Tsukuba (*Y. Ogura* TI), Gunma Prefecture. Nakazato-mura, Mt. Kanouyama (*J. Murata 7304* TI), **Chiba Prefecture.** Tomitsu-city, Mt. Nokogiri (*M. Mizushima s. n.* TI), Amatsukominato-cho, Mt. Kiyosumi (*T. Nakai s. n.*-Holotype TI as *Arisaema aequinoctiale* Nakai *et* F. Maekawa *J. Murata 163* TI, *S. Serizawa 13713-13735* AICH, *T. Kobayashi 14931-14940* SHO), Wada-cho, Wadaura (*J. Murata 152* TI), Chikura-cho, Mt. Takatsuka (*G. Murata & H. Koyama 30214* KYO), Chikura-cho, Ooikura (*G. Murata & H. Koyama 30198* KYO), **Saitama Prefecture.** Chichibu-city, Irikawa (*S. Serizawa 9628-9630* AICH), Takigawa (*S. Serizawa 9574* AICH), Chichibu-city, Hosokubo (*H. Ohashi et al.* TI), **Tokyo Metropolis.** Okutama-cho, Ogawa-dani (*S. Serizawa 15580-15583, 15593, 15594, 15596-15598, 15610-15613, 19223* AICH), Okutama-cho, Kawagoke-dani (*S. Serizawa 3582, 20720* AICH), Okutama-cho, Ootanbagawa (*S. Serizawa 20752, 23794* AICH), **Kanagawa Prefecture.** Hakone-cho, Mt. Kintoki (*K. Hisauti s. n.*-lectotype TI as *Arisaema stenophyllum* Nakai *et* Maekawa, *S. Serizawa 29379* AICH), Hakone-cho, Mt. Kamiyama (*H. Yamamoto 2112* KYO, *S. Serizawa 15734-15753* AICH), Nishikasugano-mura (*Y. Furuse s. n.* KYO), Fudakake, Mt. Tanzawa (*H. Kanai 3165* TI), **Yamanashi Prefecture.** Kawaguchiko-cho, Mitsu-touge (*K. Hasegawa s. n.* TI), Yamanakako-mura, Hirano-Nagaike (*Y. Tateishi s. n.* TI), Shimobe-cho, Tochishiro (*Y. Quadota 4143* TI), **Shizuoka Prefecture.** Susono-city, Juurigi (*S. Serizawa 28049* AICH), Fuji-city, Mt. Echizendake (*S. Serizawa 28026-28030* AICH), Susono-city, Mt. Kurodake (*H. Kanai 6828* TI, *T. Kobayashi 35950* SHO), Kanmami-cho (*T. Kobayashi 35981-35982* SHO), Kasuga-cho, Keta (*G. Murata & M. Hotta 202* KYO), **Nagano Prefecture.** Ookuwa-mura, Ajigawa (*J. Murata 9329* TI), **Gifu Prefecture.** Mino-city, Mt. Hyougatake (*H. Takahashi et al. 277* KYO), Mase-cho, Kawakami (*N. Nimura 16060* Natural Museum of Gifu Prefecture), Kanayama-cho, Yumikake (*N. Nimura 16113* Natural Museum of Gifu Prefecture), Gero-cho, Taruyama (*N. Nimura 11197* Natural Museum of Gifu Prefecture), Gero-cho, Norimasa (*N. Nimura 3125* Natural Museum of Gifu Prefecture), Gero-cho, Ogawa (*N. Nimura 8181* Natural Museum of Gifu Prefecture), Hachiman-cho, Hatohata (*T. Goto s. n.* Natural Museum of Gifu Prefecture), Kakobo-mura, Watarai-onsen (*N. Nimura s. n.* Natural Museum of Gifu Prefecture), Hagiwara-cho, Mt. Gozen (*G. Murata et al. 92* KYO, *N. Nimura 1092* Natural Museum of Gifu Prefecture), Miyama-cho, Kanzaki (*K. Seto 17068* OSA, *S. Serizawa s. n.* AICH), Miyama-cho, Natsusaka-dani (*T. Kobayashi 35690* SHO), Neo-mura, Midori-dani (*S. Serizawa 27735* AICH), **Aichi Prefecture.** Mt. Danto (*S. Serizawa 29323-29328, 29330-29332* AICH), Foraiji-mura, Ootsu-dani (*K. Torii 8093* TI), Shimane Prefecture. Mt. Suzuno-ootani (*S. Kurata s. n.* KYO), Hiroshima Prefecture. Hirosima-city, Ugakei (*S. Serizawa 27942* AICH), **Yamaguchi Prefecture.** Toyoda-cho, Mt. Kuruso (*S. Serizawa 29072* AICH), Mito-cho, Ookizu (*S. Serizawa s. n.* AICH), Tokuchi-cho, Mitani (*H. Masaki 35230* AICH), **Tokushima Prefecture.** Yamashiro-cho, Mt. Nogaike

(*C. Abe 32360* AICH, *S. Takato 29* KYO, *T. Kobayashi 30240* SHO), **Kochi Prefecture.** Sakinohama (*T. Yoshinaga s. n.*-Holotype TI as *Arisaema yosinagae* Nakai), Motoyama-cho, Mt. Ishiku, (*S. Serizawa 15534* AICH, *T. Yoshinaga s. n.* TI), **Ehime Prefecture.** Nii-gun, Kadono (*K. Ochi 7* KYO), Niihama-city, Touhira (*T. Kobayashi 17738* SHO), Mt. Goryo (*M. Mitsui s. n.* TNS)

2) *Arisaema limbatum* Nakai et F. Maekawa ex F. Maekawa (Mimigata-tennansho)
(Voucher specimens)
Miyagi Prefecture. Ojika-cho, Isl. Kinkazan-tou (population L1, *T. Kobayashi 35749-35755* SHO), **Ibaragi Prefecture.** Makabe-cho, Mt. Tsukuba (population L2, *T. Kobayashi 35737-35742* SHO), **Saitama Prefecture.** Arakawa-mura, Urayama (population L3, *T. Kobayashi 35701-35704* SHO), **Tokyo Metropolis.** Akiruno-city, Ikusamichi (population L4, *T. Kobayashi 32721-32727* SHO), **Hyogo Prefecture.** Mihara-cho (populations L5 and L6, *T. Kobayashi 25025, 26864, 26865, 26870, 35760-35762* SHO), Goshiki-cho (population L7, *T. Nanko s. n.* SHO), **Ehime Prefecture.** Seikai-cho, Isl. Shika-shima (population C1, *T. Kobayashi 26831* SHO), **Kochi Prefecture.** Sukumo-city, Isl. Okinoshima (population C2, *J. Murata 7110* TI)
(Specimens examined)
Iwate Prefecture. Morioka-city, Ooshida (*T. Makino s. n.* MAK), Madaki-mura (*G. Toda s. n.* TI), **Miyagi Prefecture.** Ojika-cho, Isl. Kinkazan-tou (*S. Serizawa s. n.* AICH), Ojika-cho (*T. Kobayashi 35745-35747* SHO), Megawa-cho, Megawakou (*S. Serizawa s. n.* AICH), Kisennuma-city, Kisennuma (*G. Toda s. n.* TI), **Fukushima Prefecture.** Higashishirakawa-gun, Mt. Yamizosan (*K. Sohma & H. Ohashi 5* TNS), **Tochigi Prefecture.** Unganji, Nasu (*S. Kitamura s. n.* KYO), **Gunma Prefecture.** Karuizawa-cho, Usui-touge (*H. Hara 844* TI), Nakazato-mura, Kamigahara (*J. Murata 7252* TI), **Ibaragi Prefecture.** Koise-mura (*Tsurumachi s. n.* KYO), **Saitama Prefecture.** Arakawa-mura, Mt. Mitsumine (*M. Togashi s. n.* TI, *S. Serizawa 27794* AICH), Mituminegùchi (*T. Kobayashi 35696-35698* SHO), **Tokyo Metropolis.** Hachiouji-city, Mt. Jinba (*S. Serizawa 23696* AICH), Myoou-touge (*S. Serizawa s. n.* AICH), Mt. Takao (*G. Koidzumi* KYO, *S. Yano s. n.* TI), Mt. Ootake (*S. Okuyama s. n.* KYO), Minamitakao (*S. Serizawa 13702* AICH), Hinokibara-mura, Mt. Sanzu (*S. Serizawa 23969* AICH), Itsukaichi-cho, Juurigi (*S. Serizawa 24033* AICH), Akiruno-city, Kariyose-dani (*F. Maekawa s. n.*-Holotype TI), Akiruno-city, Mt. Kariyose (*S. Serizawa s. n.* AICH), Okutama-cho, Mt. Honnita (*S. Serizawa 21511, 23826* AICH), Okutama-cho, Oosawakawanotani (*K. Teramoto s. n.* TI), **Kanagawa Prefecture.** Hakone-cho, Miyanoshita (*J. Murata 9332* TI), Isehara-city, Mt. Ooyama (*N. Kurosaki 12267, 12286* KYO), **Yamanashi Prefecture.** Tsuru-city, Kawadana (*Y. Tateishi 4366* TI), Dooshi-mura (*M. Togashi s. n.* KYO), **Hyogo Prefecture.** Mihara-cho (*N. Fukuoka, N. Kurosaki & S. Miyake 5633* SHO, *Kato, Fukuoka, Kurosaki and Miyake s. n.* SHO), **Ehime Prefecture.** Seikai-cho, Shika-shima (*S. Serizawa 29053-29061* AICH), Seikai-cho, Nuchidomari (*T. Kobayashi 26830* SHO), **Kochi Prefecture.** Sukumo-city Okinoshima (*T. Yamanaka 41991, 42025* KYO, *S. Serizawa 13645*-Holotype AICH as *A. limbatum* Nakai *et* F. Maekawa var. *conspicuum* Serizawa, *S. Serizawa 13646-13665* AICH), **Ooita Prefecture.** Kanae-cho (*M. Arakane 26995, 26996* AICH)

3) *Arisaema minus* (Serizawa) J. Murata (Harima-mamushigusa)
(Voucher specimens)
Hyogo Prefecture. Kobe-city, Suma-ku (population M4, *T. Kobayashi 31435-31437, 32735-32738* SHO), Kobe-city, Nishi-ku, Igawadani-cho (population M3, *T. Kobayashi 20184, 31449, 31460* SHO), Kobe-city, Nishi-ku, Yamada-cho (population M2, *T. Kobayashi 10211, 13410, 15270, 25673, 36024, 36027* SHO), Sayo-gun, Nanko-cho (population M1, *T. Kobayashi 12813* SHO)
(Specimens examined)
Hyogo Prefecture. Sayo-gun, Nanko-cho (*G. Murata 10565* KYO, *J. Murata 9578* **TI**, *S. Serizawa 27838* -Holotype AICH as *A. kishidae* var. *minus*)

4) *Arisaema nambae* Kitam. (Takahashi-tennansho)
(Voucher specimens)
Okayama Prefecture. Niimi-city (population N1, *T. Kobayashi 28526, 28871, 28872, 36008-36009* SHO, OSA)
(Specimens examined)
Okayama Prefecture. Kamogawa-cho, Kamo National Forest (*R. Nishihara s. n.* TNS), Takahashi-city (*Z. Tashiro s. n.* KYO, *S. Nanba s. n.* -Holotype KYO, *S. Nanba s. n.*-Isotype **TI**, *S. Takato s. n.* KYO, *T. Kobayashi 14930* SHO), **Hiroshima Prefecture.** Shinichi-cho, Fujio (*Z. Tashiro s. n.* KYO)

5-a) *Arisaema undulatifolium* Nakai (Nagaba-mamushi-gusa)
(Voucher specimens)
Shizuoka Prefecture. Amagiyugashima-cho, Amagi National Forest (population U1, *T. Kobayashi 35648-*

35649 SHO), Amagiyugashima-cho, Nekkogawa (population U2, *T. Kobayashi 35651* SHO)
(Specimens examined)
Shizuoka Prefecture. Amagiyugashima-cho, Mt. Amagi (*M. Ogata s. n.* TI, *T. Kobayashi 32393* SHO), Amagiyugashima-cho, Haccho-ike (*M. Hotta 1740* KYO), Amagiyugashima-cho, Amagi-touge (*S. Serizawa 39763, 39768, 39781, 39789* AICH, *T. Kobayashi 17933* SHO), Amagiyugashima-cho, Jorenno-taki (*T. Nakai s. n.*-Holotype TI), Amagiyugashima-cho (*S. Serizawa 21740, 27727* AICH), Amagiyugashima-cho, Nekko-touge (*J. Sugimoto s. n.* KYO)

5-b) *Arisaema undulatifolium* Nakai subsp. *uwajimense* T. Kobayashi et J. Murata (Uwajima-tennansho)
(Voucher specimens)
Ehime Prefecture. Uwajima-city, Nametoko-valley (population Y6, *T. Kobayashi 34219-34222, 36846-36849, T. Kobayashi 34223*-Holotype KYO), Jouhen-cho, Souzu (population Y7, *T. Kobayashi 26837, 26838* SHO), **Kochi Prefecture.** Tosashimizu-city, Mt. Imanoyama (population Y8, *T. Kobayashi 36850-36852* SHO)
(Specimens examined)
Ehime Prefecture. Jouhen-cho, Souzu (*S. Serizawa 29065-29069, 36525-36533* AICH), **Kochi Prefecture.** Sukumo-city, Sasayama (*S. Serizawa 36509* AICH), Sukumo-city, Sasahira-Oohira (*S. Serizawa 36511* AICH), Tosashimizu-city, Imanoyama (*S. Serizawa 36498* AICH)

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