Bull. Natl. Mus. Nat. Sci., Ser. B, 48(2), pp. 53–59, May 20, 2022
DOI: 10.50826/bnmnsbot.48.2_53

The Distribution of *Pteris wulaiensis* (Pteridaceae) in Japan

Atsushi Ebihara[1,*] Yi-Shan Chao[2] and Hironobu Kanemitsu[3]

[1] Department of Botany, National Museum of Nature and Science,
4–1–1 Amakubo, Tsukuba, Ibaraki 305–0005, Japan
[2] Department of Biomedical Science and Environmental Biology,
Kaohsiung Medical University,
100, Shih-Chuan 1st Rd., Kaohsiung, 80708, Taiwan
[3] IDEA Consultants, Inc.,
1–5–12 Higashihama, Higashi-ku, Fukuoka-shi, Fukuoka 812–0055, Japan
*E-mail: ebihara@kahaku.go.jp

(Received 8 February 2022; accepted 23 March 2022)

Abstract The distribution of *Pteris wulaiensis* in Japan was reassessed based on herbarium specimens, and its distinguishing characters from *P. oshimensis* var. *oshimensis* were revised and improved. A total of 47 specimens of *P. wulaiensis* were identified and the localities extend to four prefectures (Wakayama, Nagasaki, Miyazaki and Kagoshima). In Japan, *Pteris wulaiensis* has been repeatedly collected in southern Kyushu, but apparently rare in Kii Peninsula (Wakayama Prefecture) and in Fukuejima Island off the west coast of Kyushu (Nagasaki Prefecture).

Keywords: herbarium specimen, Kagoshima Prefecture, Miyazaki Prefecture, Nagasaki Prefecture, Wakayama Prefecture.

Pteris fauriei Hieron. and its closely related species having bipinnatified laminae form a species complex and are particularly diversified in East Asia (Chao *et al.*, in press). *Pteris wulaiensis* C.M.Kuo, a member of the complex described from Taiwan, was recently discovered in Japan based on molecular data (Chao *et al.*, 2021). Chao *et al.* (2021, in press) noticed that "*Ebihara et al. 3234*" a specimen collected in Saito-shi, Miyazaki Prefecture, Japan originally identified as *P. oshimensis* Hieron. var. *oshimensis* showed completely different genotypes of nuclear DNA markers (*Knox3* and *IBR3*) from those of other conspecific samples. They also noticed that its frond morphology and genotype matched *P. wulaiensis*, and concluded that it is a new record of *P. wulaiensis* in Japan (Fig. 1). Chao *et al.* (2021) cited a total of seven herbarium specimens collected in Japan (five from Kagoshima Pref. and two from Wakayama Pref.) which are identified based on their morphological characters, but its whole distribution range and abundance have not yet been investigated. To disseminate the recognition of *P. wulaiensis* in Japan and to assess its conservation priority, we explored the species by thoroughly examining herbarium specimens.

Materials and Methods

All the specimens identified as *Pteris oshimensis* deposited in the herbarium of National Museum of Nature and Science (TNS) were examined. The voucher specimens of the distribution data of *P. oshimensis* in Japan (Ebhiara and Nitta, 2019) deposited in the herbaria other than TNS were also examined by viewing the images.

The identification of *P. wulaiensis* basically followed the key provided by Chao *et al.* (2021), but it was slightly modified reflecting our present observation results (the details are described in Discussion).

Fig. 1. *Pteris wulaiensis* in Japan. a. *Ebihara et al. 3234* (TNS VS-1176826) a specimen collected in Minou, Saito-shi, Miyazaki Pref.; b. *Ebihara et al. 3234* cultivated in Tsukuba Botanical Garden (photographed on Jan. 28, 2021); c. the bases of lateral pinnae (TNS VS-1176826); d. *T. Yamanaka s.n* (TNS VS-742621) a specimen collected in Tashiro, Ohkuchi-shi, Kagoshima Pref.).

Results

We examined a total of 522 specimens and/or specimen images (506 in TNS, seven in TOFO, two each in KYO, OSA and URO, one each in CBM, KYO and RYU). Forty-one specimens were newly identified as *P. wulaiensis*, but two specimens cited as *P. wulainesis* in Chao *et al.* (2021) were removed due to their atypical frond morphology. A total of 47 specimens of *P. wulaiensis* in Japan were used for drawing a horizontal distribution map. The distribution is extended from Honshu (SE part of Kii Peninsula, Wakayama Prefecture) to Kyushu (Nagasaki, Miyazaki and Kagoshima Prefectures), but not found in Shikoku.

Discussion

According to Chao *et al.* (2021), the following three characters are used in the key to segregate *P. wulaiensis* from *P. oshimensis* var. *oshimensis* (Fig. 2): 1) red-brown colored stipe base (vs. green or stramineous in *P. oshimensis*); 2) quadrangular cross section of stipes (vs. round in *P. oshimensis*); 3) narrowed base of lateral pinnae (vs. widest base in *P. oshimensis*). However, we realized that stipe color is not always useful as a key character after examining a large number of "*P. oshimensis*" specimens collected in Japan; i.e. red-brown stipe base was occasionally observed in *P. oshimensis*. Observation of the cross section of stipes is difficult in herbarium specimens. As a result, the most reliable character for identification in specimens is shapes of lateral pinna bases. We found several additional traits which often help their identification. Firstly, fertile segment apices of *P. wulaiensis* are broadly rounded (vs. acute to subobtuse in *P. oshimensis*). Secondly, the number of lateral pinna pairs is rarely more than seven in *P. wulaiensis* (vs. 5 to 13 pairs in *P. oshimensis*). Thirdly, color of the lamina is pale green in *P. wulaiensis* (vs. green in *P. oshimensis*). Even though these characters (summarized in Table 1) were observed, segregation of *P. wulaiensis* was not an easy task in incomplete specimens (i.e. sterile, juvenile and severely damaged).

Our identification result (Fig. 3) suggested that *P. wulaiensis* is distributed neither in easternmost distribution area of *P. oshimensis* (i.e. Kanto district and Izu Peninsula) nor in Ryukyu Islands. In the southern part of Kii Peninsula, only two localities were found in Wakayama Prefecture among sporadically present localities of *P. oshimensis*, and it is suggested *P. wulaiensis* is a not a common species in Kii Peninsula. In Kyushu, its distribution is almost limited to the southern part (Miyazaki and Kagoshima Prefectures), and approximately 20 localities were found there. In addition, a locality was found in Fukuejima Island located off the west coast of Kyushu, Nagasaki Prefecture. The synthesized locality information based on the specimens suggests that *P. wulaiensis* in Japan prefers forest floors in hilly areas (elevation less than 500 m) in the warm temperate zone that do not directly face the coast.

Although the Japanese populations of *P. wulaiensis* have been erroneously merged into *P. oshimensis*, the number of reidentified specimens of *P. wulaiensis* from the collections of *P. oshimensis* is lower than true *P. oshimensis* in all the prefectures. The number probably implies that the occurrence frequency of *P. wulaiensis* in Japan is lower than *P. oshimensis*, and it might be necessary to consider the conservation of *P. wulaiensis* as a regional endangered species. In particular, the population of Wakayama Prefecture, which is the northeastern limit of its distribution, has not been investigated for 40 years since the last collection. As there is no information on the current situation, an urgent re-investigation is required.

One of the reasons that *P. wulainesis* has been overlooked in Japan is a wide range of morphological variation observed in *P. oshimensis*. Nakato and Ebihara (2016) clarified that the populations of *P. oshimensis* in Amami Islands are sexually reproducing diploid in contrast to apogamous populations in other parts of Japan. Furthermore, Chao *et al.* (in press) found difference

Fig. 2. Representative specimens of *Pteris oshimensis* var. *oshimensis*. a. The sexual form only found in Amami Islands (TNS VS-311030); b. bases of lateral pinnae of the same specimen; c. the apogamous form widely distributed in Japan (a specimen collected in Miyazaki Pref., TNS VS-344711); d. bases of lateral pinnae of the same specimen.

Table 1. A morphological comparison between *Pteris wulaiensis* and *P. oshimensis* var. *oshimensis*

	Pteris wulaiensis	*Pteris oshimensis*
Shape of lateral pinna base	slightly narrowed	widest at base
Shape of lamina segment apices	broadly rounded	acute to subobtuse
Number of lateral pinnae	3–5(–7) pairs	5–13 pairs
Color of laminae	pale green	green
Color of stipe base	usually green or stramineous	usually red-brown
Shape or cross section of stipe	quadrangular	round

between the sexual individuals and the apogamous ones in their genomic formula identified by nuclear DNA markers–apogamous *P. oshimensis* originated in hybridization between sexual *P. oshimensis* and an unknown species. As Chao *et al.* (in press) sampled only a limited number of populations of apogamous *P. oshimensis* in Japan (Mie and Miyazaki Prefectures), there is still the possibility of presence of other genomic formulae among the apogamous populations. Thus, further sampling and subsequent taxonomic treatment are necessary for *P. oshimensis* and its closely related species.

Specimens examined

Pteris wulaiensis C.M.Kuo, Bot. Bull. Acad. Sin. 30: 143(–145), 1989.

Japanese name: Wulai (Urai)-hachijo-shida

JAPAN: **Wakayama Pref.**, Higashimuro-gun, Kozagawa-cho, Nakazaki, Misatodani (*K. Ohora s.n.*, 1981-12-13, TNS VS-1165865); Higashimuro-gun, Sirahama-cho, Shagawa (*T. Iwasaki 548*, 1970-5-5, TNS VS-808606); ibid. (*T. Iwasaki 549*, 1970-5-5, TNS VS-808605); ibid. (*T. Iwasaki 550*, 1970-5-5, TNS VS-808607); ibid. (*T. Iwasaki 551*, 1970-5-5, TNS VS-808608); ibid. (*T. Iwasaki 552*, 1970-5-5, TNS VS-808609); ibid. (*T. Iwasaki 553*, 1970-5-5, TNS VS-808610); ibid. (*T. Iwasaki 1176*, 1970-8-22, TNS VS-808613); ibid. (*T. Iwasaki 1177*, 1970-8-22, TNS VS-808614); ibid. (*T. Iwasaki 1178*, 1970-8-22, TNS VS-808585); ibid. (*T. Iwasaki 1179*, 1970-8-22, TNS VS-808615); ibid. (*T. Iwasaki 1180*, 1970-8-22, TNS VS-808616); ibid. (*T. Iwasaki 1183*, 1970-8-22, TNS VS-808617); ibid. (*T. Iwasaki 1572*, 1971-1-4, TNS VS-808621); ibid. (*T. Iwasaki 1573*, 1971-1-4, TNS VS-808619); ibid. (*T. Iwasaki 1574*, 1971-1-4, TNS VS-808618).

Nagasaki Pref., Goto-shi, Fukuejima Isl., Gomachi, Sasadake (*Y. Inoue AE3718*, 2019-5-12, TNS VS-1313421).

Miyazaki Pref., Saito-shi, Minou, alt. 59 m (*A. Ebihara et al. 3234*, 2012-11-28, TNS VS-1176826); ibid. (*A. Ebihara et al. 3236*, 2012-11-28, TNS VS-1176828); ibid. (*A. Ebihara et al. 3239*, 2012-11-28, TNS VS-1176831); Saito-shi, Tsuzushi (*T. Minamitani 25389*, 1977-9-11, TNS VS-364992); Saito-shi, Uchikoshi, alt. 400 m (*Y. Akagi MZA356*, 2007-3-21, TNS VS-1200495); Morokata-gun, Aya-cho, Irino, alt. 59 m (*A. Ebihara et al. KS2007-257*, 2007-2-22, TNS VS-762742); .

Kagoshima Pref., Kagoshima-shi, Yoshinocho, Iso (*M. Maeda s.n.*, 1975-9-7, TNS VS-365184); Kagoshima-shi, Hida (*K. Takesako s.n.*, 1973-8-?, TNS VS-344495); Izumi-shi, Utsura (*T. Yamanaka s.n.*, 1962-11-23, TNS VS-344437); Izumi-shi, Utsuragoe (*T. Yamanaka s.n.*, 1963-9-8, TNS VS-777391); Izumi-shi, Mt. Shibisan, Nagareai (*S. Kurata 824*, 1957-8-14, TNS VS-1033412); Izumi-shi, Nagareai [cult. Tsukuba Botanical Garden] (*S. Matsumoto et al. SM080211-51*, 2008-2-11, TNS VS-1329464); Mt. Shibisan (*K. Naohara s.n.*, 1930-11-1, TNS VS-808503); Ohkuchi-shi, Heboki (*T. Yamanaka s.n.*, 1975-1-3, TNS VS-778192); Ohkuchi-shi, Tashiro (*T. Yamanaka s.n.*, 1959-2-8, TNS VS-742621); ibid. (*T. Yamanaka s.n.*, 1959-8-16, TNS VS-1112234); ibid. (*M. Kido 10787*, 1970-8-17, TNS VS-365147); ibid. (*T. Yamanaka s.n.*, 1989-3-10, TNS VS-779601); Satsuma-gun, Tsuruda-mura, Hirae (*T. Yamanaka s.n.*, 1960-9-11, TNS VS-344484, 735175); Satsuma-gun,

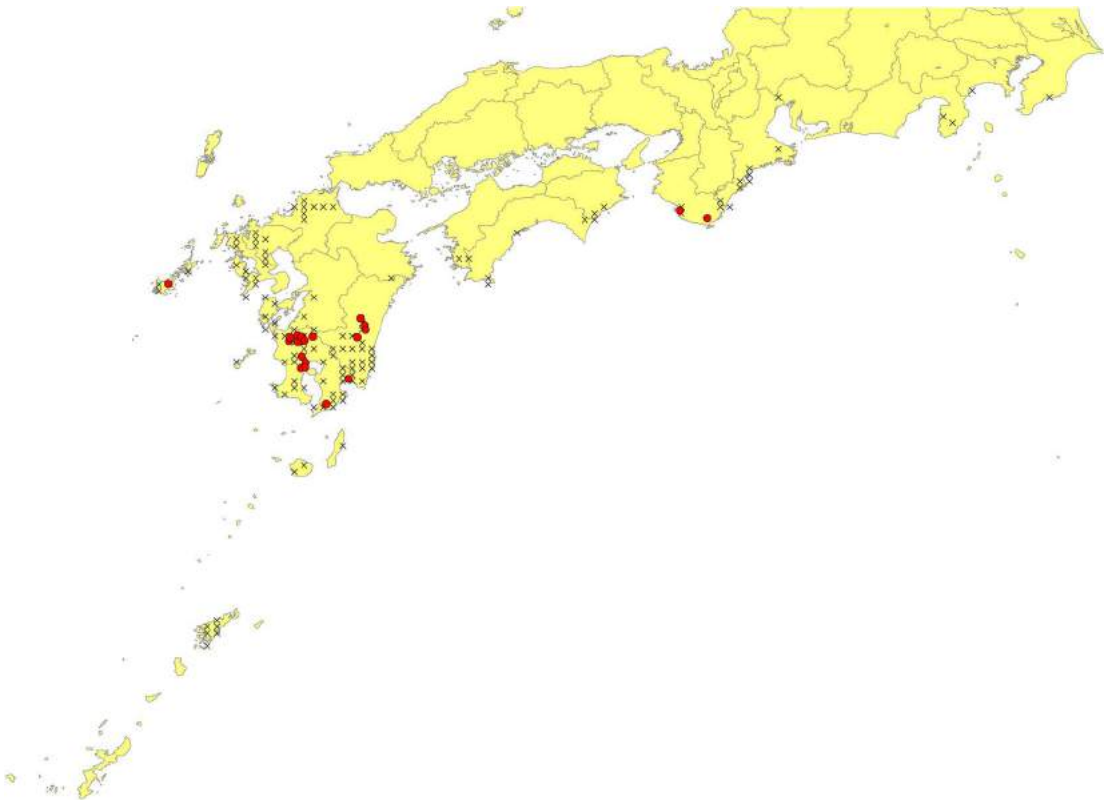

Fig. 3. A distribution map of *Pteris wulaiensis* and *P. oshimensis* in Japan. Circle: the localities of cited specimens of *P. wulaiensis*; cross mark: *P. oshimensis* based on Kurata and Nakaike (1979).

Tsuruda-mura, Gori National Forest (*S. Kurata 8883*, 1961-8-22, TNS VS-365282); Satsuma-gun, Tsuruda-mura, Gori (*M. Kido 4142*, 1961-8-22, TNS VS-344496); Satsuma-gun, Tsuruda-cho, Gori (*T. Yamanaka s.n.*, 1965-7-18, TNS VS-1112189); Satsuma-gun, Tsuruda-cho, Miko, Ohmata National Forest (*S. Ohtani s.n.*, 1968-8-5, TNS VS-344385); Isa-gun, Hishikari-cho, Kusumoto (*T. Yamanaka s.n.*, 1961-1-15, TNS VS-365318); ibid. (*T. Yamanaka s.n.*, 1975-9-24, TNS VS-1114418); Soo-gun, Shibushi-cho, Masukura (*K. Takesako 4548*, 1976-8-17, TNS VS-365191); Aira-gun, Kamoh-cho, Shirao (*M. Heki 5732*, 1964-10-31, TNS VS-344450); Aira-gun, Aira-cho, Shigetomi (*M. Heki 4184*, 1961-11-3, TNS VS-365139); Kimotsuki-gun, Tashiro-cho, Hanaze (*S. Mitsuta s.n.*, 1971-3-25, TNS VS-344468); .

Acknowledgments

The authors thank Y. Inoue, T. Minamitani and T. Oka for collecting samples. This study was supported by the Environment Research and Technology Development Fund (JPMEERF20204001) of the Ministry of the Environment, Japan.

References

Chao, Y.-S., Chiou, W.-L., Ebihara, A., Hsu, T.-C., Chang, Y.-H. and Lin, C.-Y. 2021. Taxonomic and nomenclatural novelties in the *Pteris fauriei* group (Pteridaceae). Taiwania 66: 307–316.

Chao, Y.-S., Ebihara, A., Chiou, W.-L., Tsai, J.-M., Huang, Y.-W. and Ranker, T. A. in press. Reticulate evolution in the *Pteris fauriei* group (Pteridaceae). Scientific Reports.

Ebihara, A. and Nitta, J. H. 2019. An update and reassessment of fern and lycophyte diversity data in the Japanese Archipelago. Journal of Plant Research 132: 723–738.

Kurata, S. and Nakaike, T. 1979. Illustrations of Pterido-

phytes of Japan, Vol. 1. The University of Tokyo Press, Tokyo (in Japanese).

Nakato, N. and Ebihara, A. 2016. Chromosome numbers of 18 ferns in Japan: toward completion of chromosome information in Japanese ferns. Bulletin of the National Museum of Nature and Science, Series B 42: 25–40.