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Interactive Key to Taiwan Grasses Using Characters of Leaf Anatomy – The ActKey Approach

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ABSTRACT: ActKey is an online interactive key program and database for identification of organisms. It differs from traditional dichotomous keys in providing multi-access entry points. Rather than answering questions to key couplets while following a pre-defined path, ActKey provides a wider strategy for identifying an unknown plant. The program is web-based and supports most popular internet browsers. Visitors can use interactive keys at the the www.efloras.org website as tools for identifications, and an earlier version of ActKey with over 70 interactive keys can be found at http://flora.huh.harvard.edu:8080/actkey/. Moreover, ActKey enables the taxonomist to create and edit a key online and publish it online instantly. The www.efloras.org website designed by Hong Song is used to host taxon- and specimen-based information, and ActKey is one of its many features. In this paper, we will demonstrate how to construct an ActKey for identifying Taiwan grasses using a character set of leaf anatomy. Fifteen characters were used. Pop-up windows display images illustrating the character states. Data from microscopic examination of sections of leaf blades of 176 species in five subfamilies of grasses in Taiwan are included. The constructed ActKey will be useful to identify Taiwan grasses especially when flowering material is unavailable.

KEY WORDS: ActKey, eFlora, Gramineae, Interactive Key, leaf anatomy, Taiwan.

INTRODUCTION

The Poaceae (Gramineae) are an economically important, large, flowering plant family that poses identification problems for specialists and non-specialists in pure and applied sciences (Clifford and Watson, 1977). There are more than 350 species of grasses in Taiwan. Several books (Hsu, 1975; Koyama, 1987; Osada, 1993) and the treatment of the family in the Flora of Taiwan (Hsu *et al.*, 2000) are the most useful references for identification of grasses of Taiwan in general.

The most frequently used method for identification of unknown plants is the dichotomous key that is found in journals, manuals, floras, and field guides. The dichotomous key is a traditional device that biologists use to identify organisms and is a major part of training in identification (Radford, 1986). Computer-based methods and a variety of interactive keys have been developed in recent years for identification (Brach and Song, 2005a, 2005b). Most differ from the dichotomous key by providing multi-access entry points, thereby eliminating the requirement to answer questions to key couplets along a pre-defined path.

DELTA-format interactive keys (e.g., Intkey) are the most popular, and are widely used for identification of most organisms (Dallwitz *et al.*, 2002 onwards). Numerous DELTA-format interactive keys for grasses worldwide (Aiken *et al.*, 1996; Clayton, 1999

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onwards; Watson and Dallwitz, 1992 onwards) including some genera of Taiwan grasses were also available (Chen and Kuoh, 2000a, 2000b). Another web-based tool, ActKey, for constructing interactive key on the web at www.efloras.org was developed recently (Brach and Song, 2005a, 2005b). ActKey has been used by many plant taxonomists for a variety of taxa, and its usage expanded rapidly. ActKey has many merits for building interactive keys. The involvement of numerous botanists and their projects resulted in improvements in the ActKey program and the eFloras website (Brach and Song, 2005a, 2005b).

Examinations of leaf anatomy have been documented by Kuoh for searching the C_4 Kranz syndrome in Taiwan grasses (Kuoh, 1985). These data are also helpful for grass identification, especially when fragment collections or non-flowering plants are encountered.

We built an interactive key for identifying Taiwan grasses from a character set of leaf anatomy based on the data in Kuoh's thesis (Kuoh, 1985) via the online tool at www.efloras.org.

MATERIALS AND METHODS

Three kinds of priori information are required before building an identification system (Radford, 1986; Brach and Song, 2005b). These primary requirements for DELTA are: the pertinent taxa, the useful differentiating characters and character-states or attributes of these taxa (CHARS, character list), the taxon/character data themselves (ITEMS, taxa with character states scored), and data specifications (SPECS). With ActKey, the character list can be built online, and the taxon data can be entered online simply by selecting the applicable states for most characters.

The pertinent taxa

The eFlora of Taiwan grasses was built first. The principal format of this flora (Fig. 1) on www.efloras.org was basically similar to that of the Flora of Taiwan (Huang *et al.*, 2000). The taxon-based and specimen-based data for each taxon were entered via the "Flora Taxon Editor" and "Flora Text Editor" and the images and/or drawings were uploaded and edited via the "Flora Object Editor" at www.efloras.org, respectively (Brach and Song, 2005a).

Character set

Fifteen characters were chosen from Kuoh's thesis (Kuoh, 1985) as follows: 1). Midrib, 2). Leaf surface, 3). Sclerenchyma, 4). Chlorenchyma, 5). Bundle sheath, 6). Bulliform cells not well developed, 7). Bulliform cells well developed, 8). No small vein under bulliform cells, 9). With small vein under bulliform cells, 10). Chlorenchyma cell number between two adjacent veins, 11), Chloroplast form in bundle sheath, 12). Mestome sheath, 13). Distance between two adjacent veins, 14). Length/width ratio of bundle sheath in LS, and 15). Chlorenchyma cell shape in LS.

The taxon/character state data

The taxon/character states for leaf anatomy includes microscopic examinations of both transverse and longitudinal sections of leaf blades of 176 species in five subfamilies of grasses (arbitrarily excluding Bambusoideae) in Taiwan documented in a previous database POAKEY.DBF (Kuoh, 1985).

Fig. 1. Part of an example page at www.efloras.org showing the format of eFlora of Taiwan grasses.

Constructing the ActKey

The process for building the ActKey is briefly described as follows:

1. Created a new ActKey, providing a name and obtaining an ID via the "Character/Data Set Editor" (Fig. 2).
2. Fifteen characters were entered and two character images were uploaded via the "Character Edit Page" (Fig. 3).
3. Entered and edited character states for each character via the "Character States Edit Page" (Fig. 4).
4. When the above processes were completed, all of the characters and their character states could be viewed via the "Character/Data Set Information" (Fig. 5).
5. Linked this character set to the taxa on the eFlora of Taiwan Grasses via "Link Taxa To Character Set" (Fig. 6).
6. Finally, entered data for each linked taxa via the "Data Entry Page" (Fig. 7).

Fig. 2. The first step of building an ActKey is to create a new character set on the Character/Data Set Editor Page at www.efloras.org

The ActKey to taxa of Taiwan grasses by characters of leaf anatomy was built together with the microphotographs of leaf cross sections. More data and taxa will be added to the eFlora of Taiwan Grasses and its corresponding ActKey when available (Fig. 8).

DISCUSSION

The Poaceae (Gramineae) is a useful test group for exploring and illustrating identification approaches, and for practical testing of new and refined methods (Clifford and Watson, 1977). We have demonstrated that constructing an interactive key at www.efloras.org is very easy and efficient from the example of constructing an ActKey for identifying Taiwan grasses using a character set of leaf anatomy. ActKey at www.efloras.org offers several specific pages (i.e., data-entry forms) in a straightforward, user-friendly way for building the character

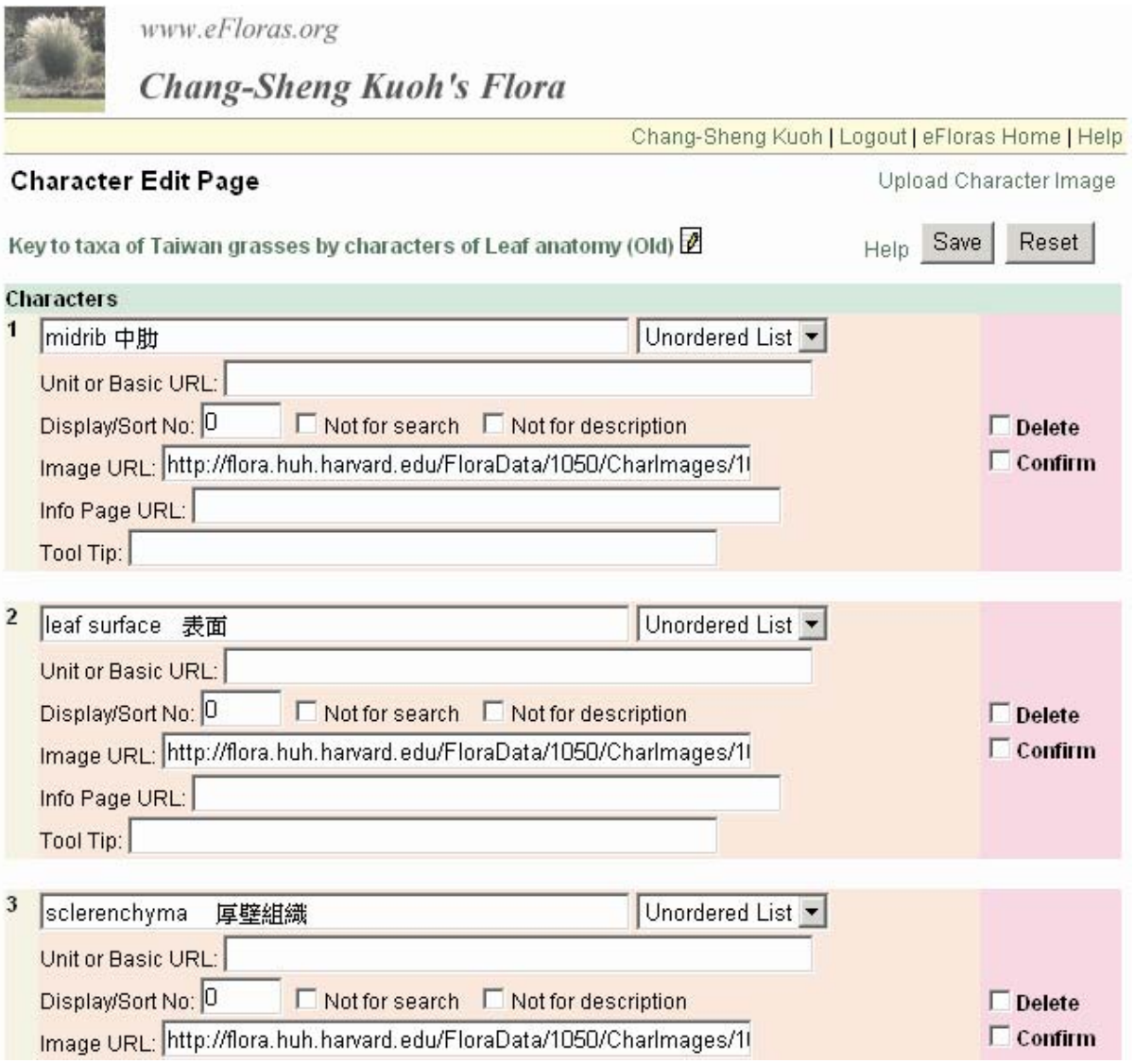

Fig. 3. Part of an example page showing the editing of a character list via the Character Edit page. Character images can be uploaded from this page.

set and entering taxon data. Once the ActKey has been built, descriptions of taxa are automatically generated on the eFlora pages. ActKey is integrated and linked with all of the information in the www.efloras.org database. We added the leaf anatomy data to the other taxon-based information via ActKey construction and it was integrated very well with specimen-based information from the project eFlora of Taiwan Grasses at www.efloras.org. Based on the same concept of interactive keys, ActKey can be used to build a checklist, catalogue, or any lists with predefined data items. More examples can be found on the same website.

The centralized, relational structure of the ActKey database and the efloras.org website offers new improvements to facilitate identification of grasses and other organisms. It enables users to enter and update their data online at anytime, from anywhere, and the results can be seen instantly.

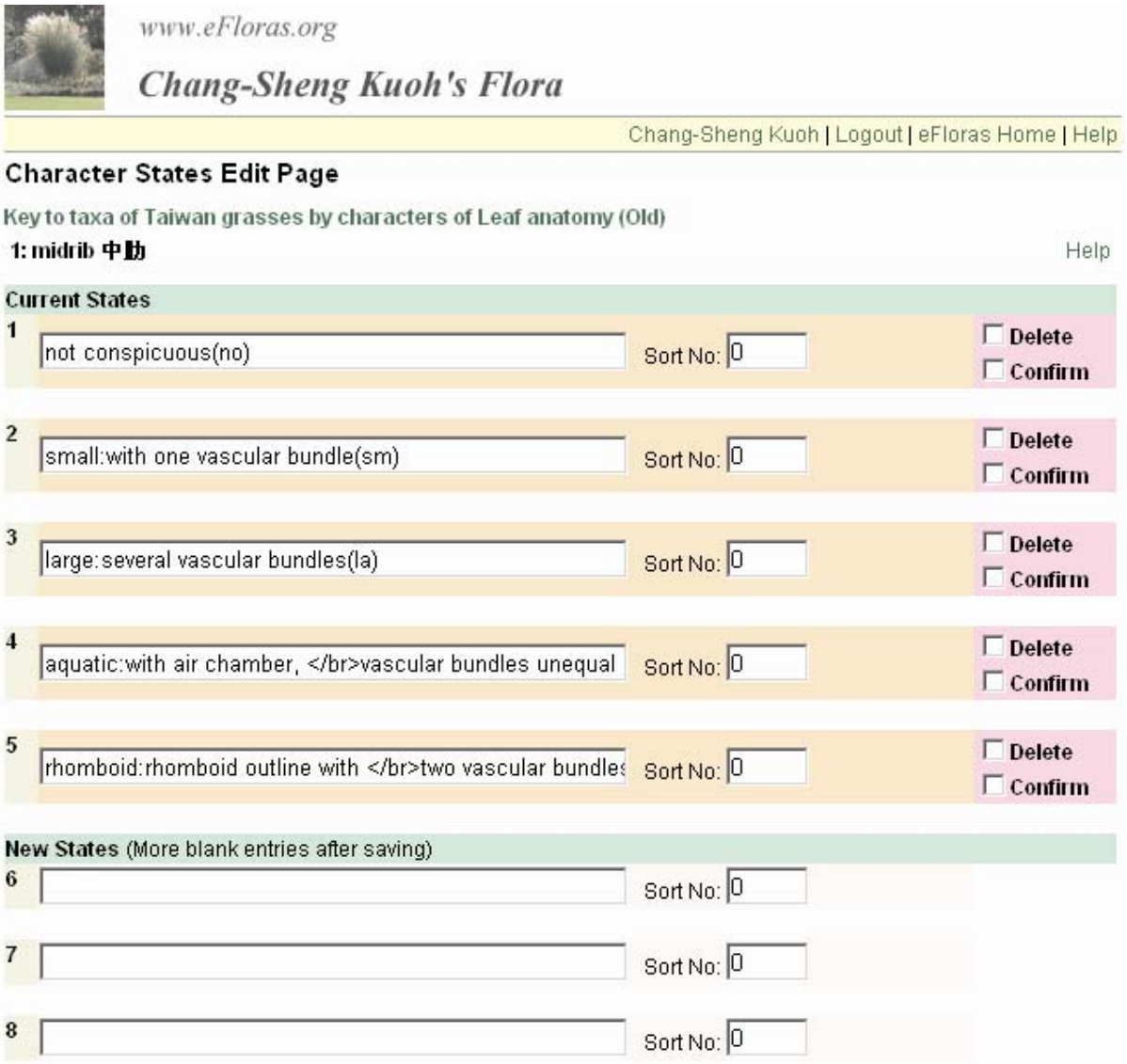

Fig. 4. Part of an example page showing entering of character states for a character via the Character State Edit page.

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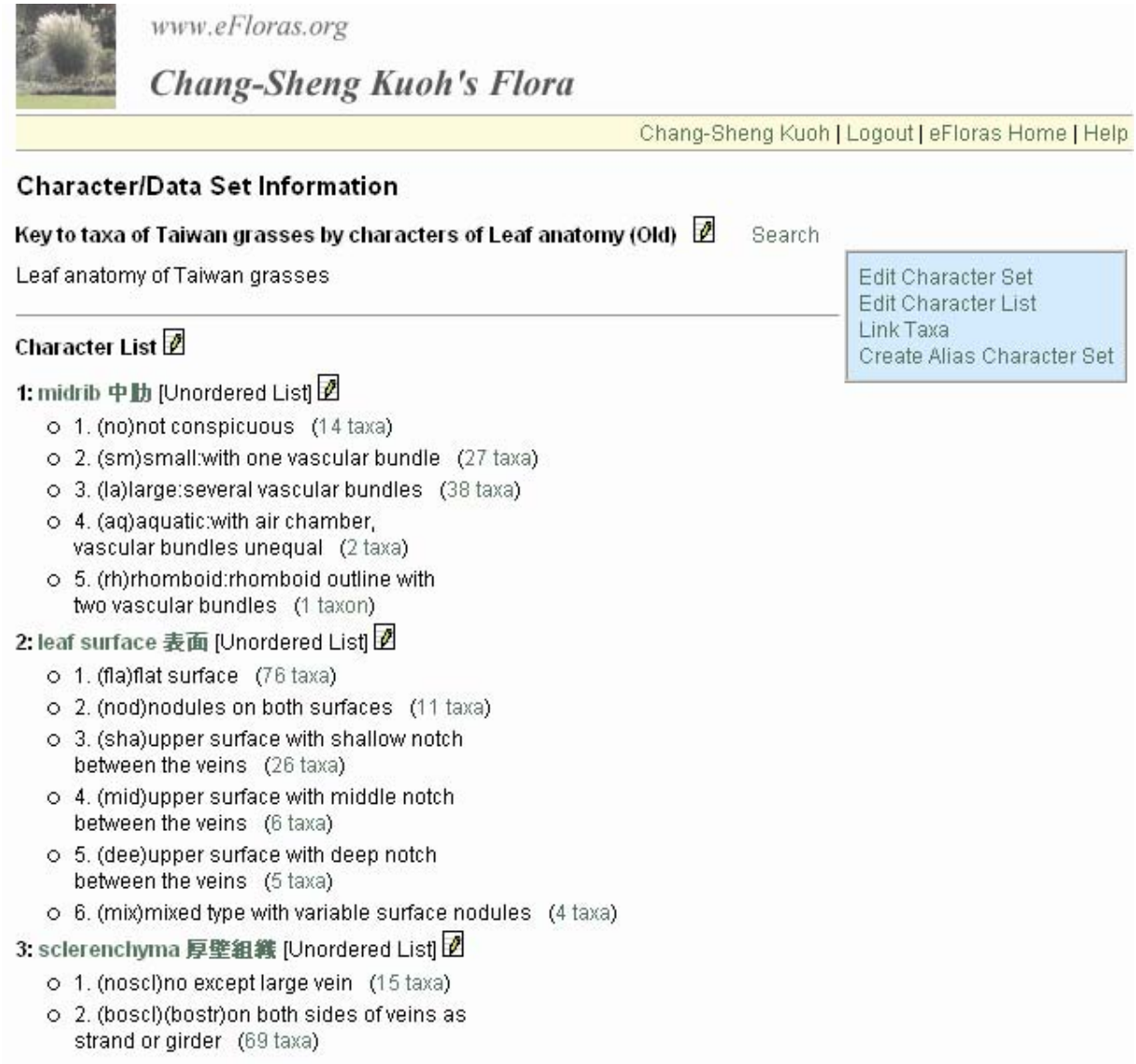

Fig. 5. The Character/Data Set Information page displays the list of all the characters and their character states. You can click the "pencil icon" to go to the Character State Edit page or click the "characters" to view the uploaded character images.

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Fig. 6. Taxa of the eFlora of Taiwan grasses can be linked to the character set by choosing from "Taxon Groups" at the Link Taxa To Character Set page. Once linked, the taxon data can be entered (See Fig. 7) and displayed using the assigned character set (See Fig. 1).

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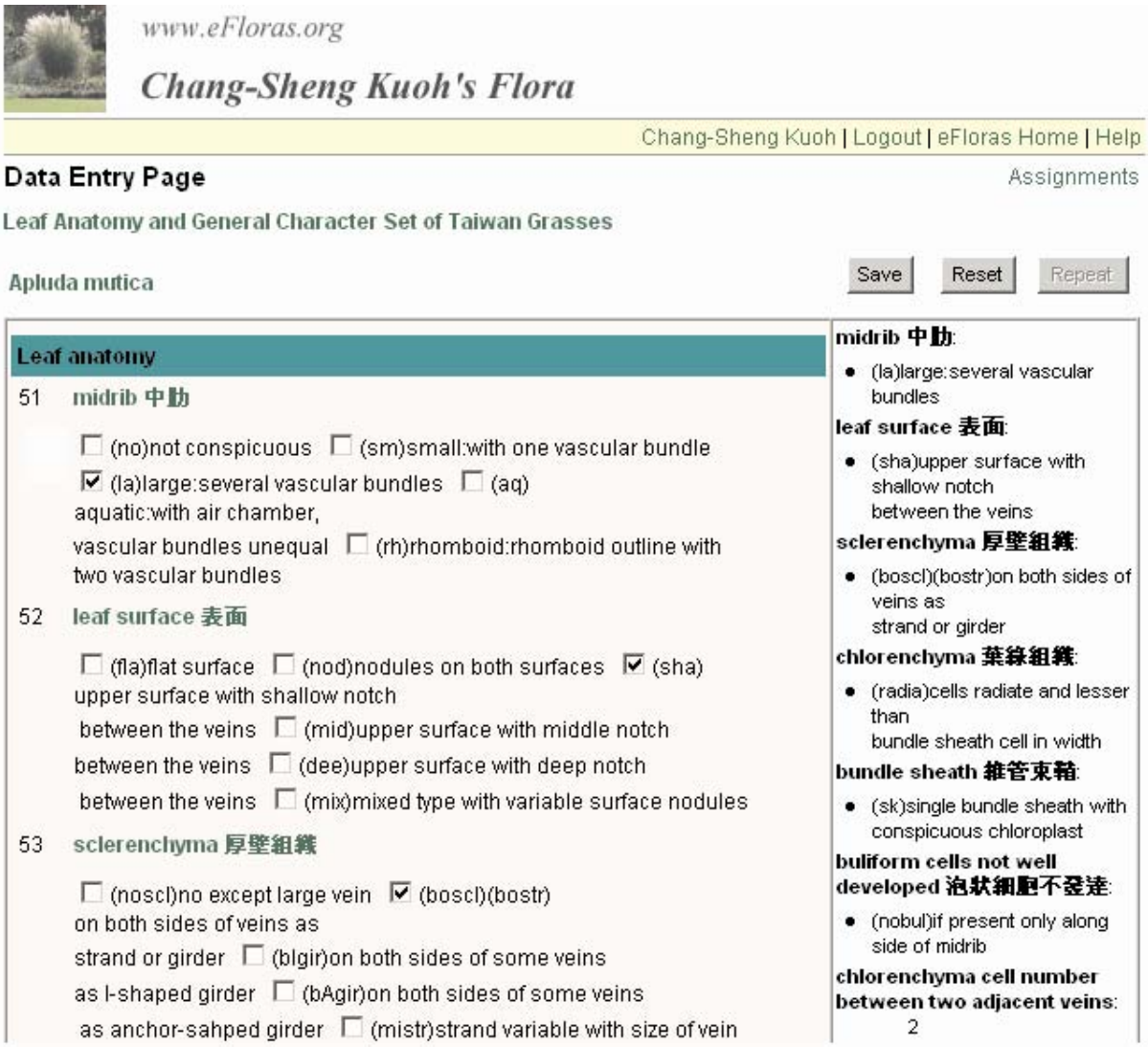

Fig. 7. Part of an example page showing data entry for a taxon by checking boxes for applicable character states on the Data Entry Page. The character descriptions of the treated taxon will be automatically produced in the right column of the same page.

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www.eFloras.org

Chang-Sheng Kuoh's Flora

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Kuoh's Flora | Family List | Poaceae | Chloris

Chloris barbata Sw., Fl. Ind. Occ. 1: 200. 1797. Hsu, Fl. Taiwan 5: 462. 1978; Koyama, Grass. Jap. Neighb. Reg. 279. 1987.

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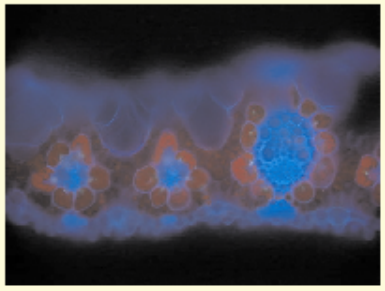
Andropogon barbatum L., Mant. Pl. Att. 302. 1771, non L. 1759. *Chloris inflata* Link, Enum. Hort. Berol. I: 105. 1821; Senaratna Grass Ceylon ; pl. 11. 1956; Keng, l. c. 466. f. 399. 1959.

Culms tufted. Blade about 1.5 mm wide, siliceous on surface; ligule ciliate , about 0.3 mm long. Inflorescence a digitate spike. Spikelets 3-flowered, about 3 mm long; glumes membranous, conspicuously 1-nerved; the lower deltoid-lanceolate, about 1.2 mm long, acute; the upper narrowly lanceolate, about 2.5 mm long, shortly awned; lower floret fertile; lemma about 2.7 mm long, chartaceous, 3-nerved, midrib extending into a long awn of 4 times the length of the lemma, margins hispid, 2-toothed; palea about 2.2 mm long, membranous, with a sinus at the apex, minutely ciliate, 2-keeled, upper part oblong, lower part linear; sterile lemma 2-lobed, 3-nerved, margins siliceous; anthers about 0.5 mm long. Caryopsis, about 1.6 mm long; embryo 1/2 as long as the caryopsis.



Chloris barbata
UV fluorescence of leaf cross section

Credit: JW Lin

NANTOU: Chitou, *Kuoh 13502*. CHIAYI: Chiayi, *De Vol 7095**. TAINAN: Hsinhua, *Wang 20080*. KAOHSIUNG: Kaohsiung, *Hsu 533-1*. PINGTUNG: Ssuchungchi, *Chang 2121*.

Distributed in the tropics of Southeast Asia, introduced elsewhere, but some authors have considered it to be a native of tropical America.

Cattle are said to be partial to this grass when it is young, but avoid it when the inflorescence matures. It has a purplish inftorescence with nearly globose sterile lemmas.

midrib 中肋: (la)large:several vascular bundles

leaf surface 表面: (fla)flat surface

sclerenchyma 厚壁組織: (abscl)on abaxial side of vein

chlorenchyma 葉綠組織: (radia)cells radiate and lesser than bundle sheath cell in width

bundle sheath 維管束鞘: (dki)two bundle sheaths the inner one with conspicuous chloroplast

Fig. 8. Part of an example page showing an additional autofluorescence image of the leaf cross section of *Chloris barbata*.

以葉解剖特徵互動式檢索台灣的禾草－ActKey 的應用

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摘　　要

ActKey是一用於鑑定物件的線上互動式檢索工具。其有別於傳統二分式檢索之處在於能夠多點查詢，不必依既定的成對特徵逐項查對。ActKey在鑑定植物時可採用不同的策略，以網路為基礎且適用於通用的瀏覽器。瀏覽者可於 www.efloras.org 網站上用它來鑑定多類植物，較早的版本於下列網頁 http://flora.huh.harvard.edu:8080/actkey/ 可找道到 70 多個互動式檢索。還有ActKey可讓分類學家在網路上及時製作和編輯一個檢索工具。宋宏設計的 www.efloras.org 網頁主要在於整合分類群與標本等資訊，而ActKey的應用是其諸多特色之一。本文以葉解剖特徵建構一ActKey供台灣禾草的鑑定。採用十五個特徵作為特徵集，彈出式視窗可顯示輔助說明特徵的影像圖片。包括台灣產禾本科五個亞科 176 種禾草的葉解剖切片顯微觀查資料。由ActKey彙整後的資料有助於台灣禾草的鑑定，特別是在缺少花部的時候。

關鍵詞：ActKey、電子植物誌、禾本科、互動式檢索、葉解剖特徵、台灣。

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