Enhancing Accessibility in Sedge Taxonomy : A Web-Based Interactive Identification Key for *Carex* of Korea

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Introduction

- *Carex* L. (Cyperaceae) is the largest genus in Northeast Asia (Wang et al., 2023), with approximately 220 taxa reported in Korea (KNA 2022; NIBR 2024). Species of this genus display remarkable adaptability, thriving in diverse habitats ranging from wetlands to arid zones. They play crucial roles in ecosystems, contributing to soil stabilization, providing habitats and sustenance for wildlife, and serving as resources in medicine and gardening (Mishra et al., 2015).
- The species of *Carex* are challenging to identify due to the high degree of morphological similarity between the taxa and the inconspicuous structures of the flowers. Therefore, accurate identification requires a combination of characters, including those observed with a loupe.

Interactive Key as an Essential Tool

- Traditional dichotomous keys have limitations in identifying *Carex* species, as the identification process is passive; if the characters used in the key cannot be observed, the steps of the identification process will not continue.
- In contrast, an interactive key system allows researchers to actively select and search for characters they can observe. The system repeats the selection of character states for identification until only one taxon remains (Dallwitz, 1974 and 1980).
- Recent practical advances in the interactive identification system have increased identification efficiency by 1) incorporating images for taxa, characters, and character states, 2) introducing the score-weight system that assigns different weights to characters based on their importance in species identification, and 3) web-based management. Commercial programs such as Lucid (LucidCentral.org, Queensland, Australia), with these features, make the deployment of taxon-specific interactive identification systems more efficient.
- Interactive key systems have recently been developed in various taxonomic groups (e. g., Guerrero et al., 2012; Sarnat, 2008; Winterton et al., 2018) to enhance the accuracy and efficiency of identification. To increase efficiency with interactive identification systems, Wäldchen et al. (2022) have suggested the following: 1) adapting to users with different levels of prior knowledge, 2) considering user behavior during the identification process, 3) incorporating uncertainty and error tolerance in the identification process, 4) designing characters with less states, 5) designing identification keys with iconic symbols, illustrations, or images.

Objectives

- This study aims to develop a web-based interactive identification system for Korean *Carex* species using commercial software Lucid 4.0 (Lucidcentral, Stafford Heights, Australia; https://www.lucidcentral.org). The system will be a valuable resource for future research and applications on *Carex*, enabling rapid and accurate identification in the field using mobile devices.

Materials and Methods

Materials

This study focused on 116 of the 222 taxa native to Korea (NIBR 2024). The system includes mostly common species, and the criteria for species selection was whether specimens were available for direct observation at the herbaria of Sungshin Women's University (SWU) and the Korea National Arboretum (KH).

Methods

Selection of Characters and Character States

- For efficient and accurate identification, the selection of the characters and character states was based on the suggestions of Wäldchen et al. (2022).
- A total of 39 morphological characters were chosen from taxon descriptions in the comprehensive literature on Korean *Carex* (Cho et al., 2016; Hoshino et al., 2011; Park et al., 2016) and direct observation of specimens deposited at SWU and KH. Six quantitative characters and 33 qualitative characters were useful in distinguishing species (**Figure 1**).
- For each taxon, the character states of the characters are recorded in a character X taxon matrix in "Lucid Builder" of Lucid 4.0 by directly confirming the character state in the relevant specimens (an example part of the matrix is shown in **Figure 2**).

Preparation of Visual Resources

- For each taxon, at least one image of a herbarium specimen or photos in the field are included in the system. Specimen images are from the herbaria of Sungshin Women's University (SWU) or Korea National Arboretum (KH).
- Images corresponding to each character and character state description were also included. Microscopic characters observed by dissection were examined and photographed using a dissecting microscope (Leica MZ APO, Germany). The images were then processed using Photoroom (Photoroom.com, Paris, France) and Adobe Lightroom (Adobe.com, San Jose, California).

Results and Discussion

- We have successfully developed a web-based interactive identification for the effective identification of Korean *Carex*. The distribution of differences between the taxon pairs is shown in **Figure 3**. The number of character states per character is set to a maximum of four to minimize errors and confusion.

Diagnostic characters for subgenera and sections

- We identified several diagnostic characters that are especially informative for separating subgenera and sections in *Carex*. First, the number of spikes is decisive: taxa with a single spike are placed in subg. *Euthyceras*, whereas those with two or more spikes fall within subg. *Carex*, *Vignea*, or *Siderosticta*. Second, shape similarity among spikes helps refine placement: when spikes are similar, taxa are assigned to subg. *Vignea*; when spikes are dissimilar, they are assigned to subg. *Carex* or *Siderosticta*.
- Multiple characters within each subgenus were consistently and usefully applied at the section level. For example, when two or more spikes come from one node, the taxa fall under sect. *Graciles*, and when the utricle bears an appendage, the taxa are assigned to sect. *Mitratae*. Together, these characters provide a clear, efficient way to identify plants more quickly and accurately.

Visual Resources

- The character states are accompanied by images of live plants that best illustrate each state, and each taxon is accompanied by dissected images of spikes, perigynium, achenes, and glumes, along with a voucher specimen from this study, to help in resolving taxonomically problematic taxa in the future and to facilitate corrections to this system.
- These enriched image resources allow users to directly compare the character state of a plant to be identified with that on the system, increasing the identification efficiency.

Accessibility and Future Plan

This interactive identification key has been temporarily opened on our website (try it with the QR code on the right). It will soon be available as a mobile application, allowing users to access it from anywhere on the web.

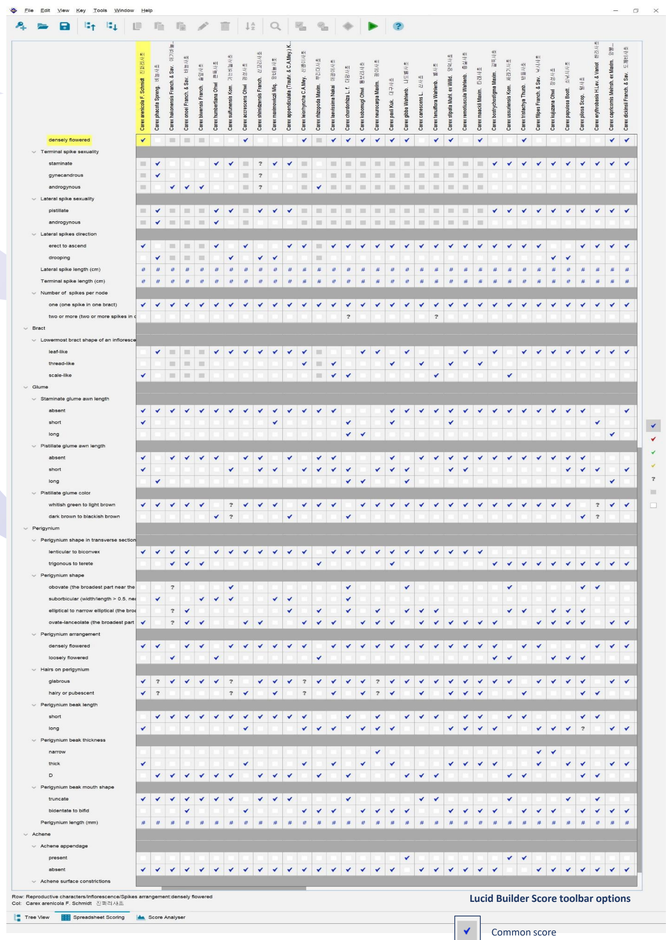


Figure 1. Screenshots of a part of the scoring spreadsheet under development in Lucid Builder (Lucid 4.0) and descriptions of score toolbar options.

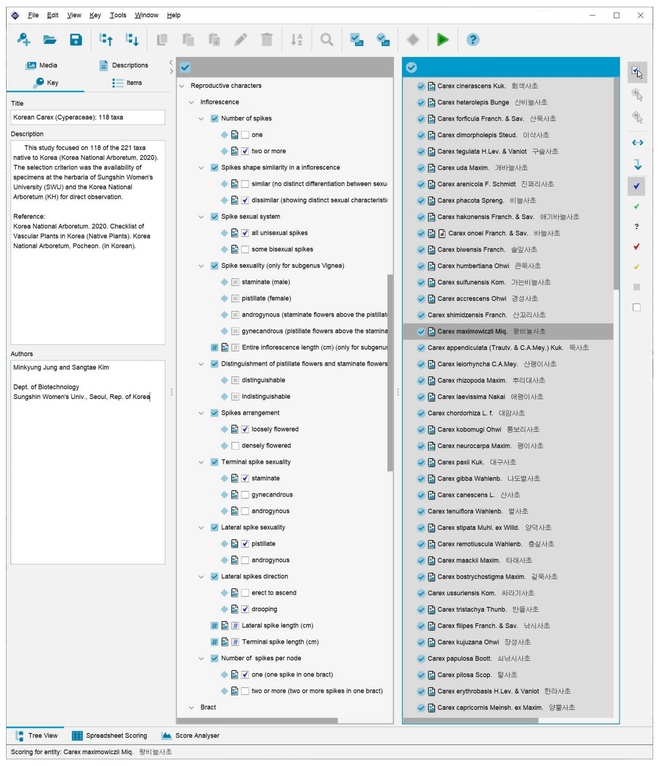


Figure 2. Screenshots of a part of the tree view mode of the scores for a single species.

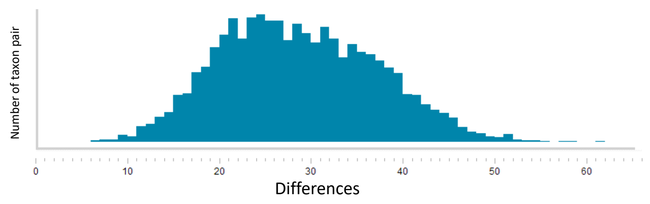


Figure 3. A bar graph showing the number of differences between all pairs of entities in the developed interactive key of this study, using the score analyzer in Lucid Builder.

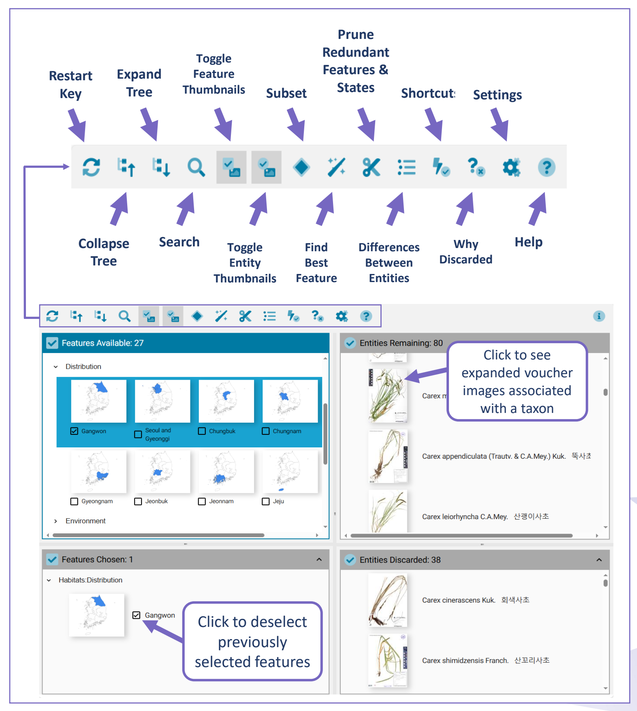


Figure 4. The toolbars and panels of the main interface in Lucid Player, along with their descriptions.

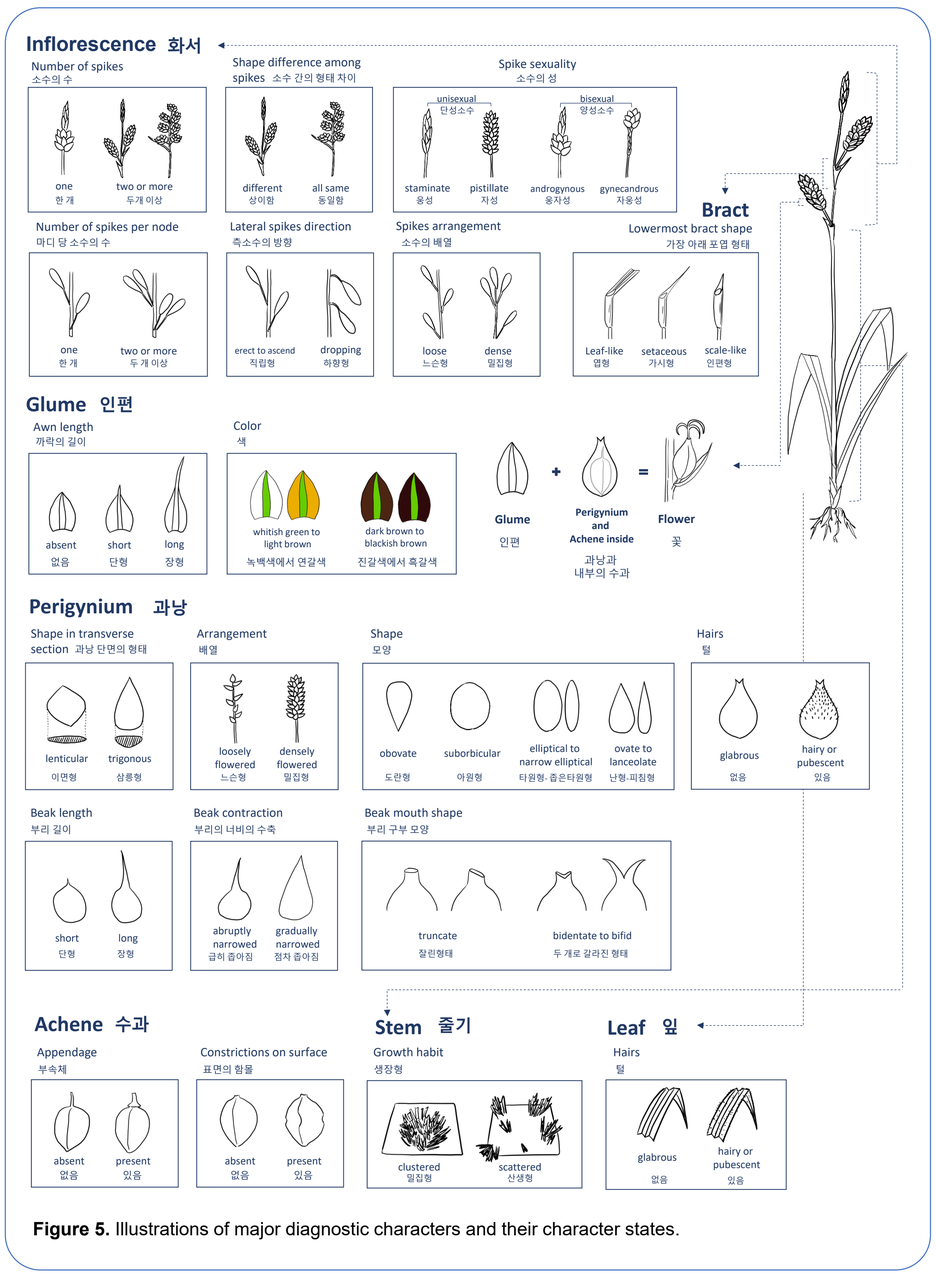
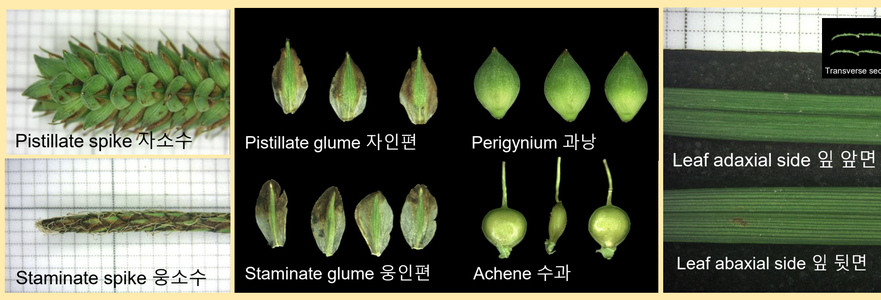


Figure 5. Illustrations of major diagnostic characters and their character states.

Try to identify a Korean *Carex* specimen below using our interactive key system

TEMPORARILY OPEN: Try to access the web-based interactive key using this QR code





References

Cho, Y.-H., Kim, J.-H., & Park, S.-H. (2016). Grasses and sedges in South Korea. Geobook. [in Korean]
Dallwitz, M. J. (1974). A flexible computer program for generating identification keys. Systematic Zoology, 23(1), 50–57.
Dallwitz, M. J. (1980). A general system for coding taxonomic descriptions. Taxon, 29(1), 41–46.
Guerrero, S., Weeks, J., Hodges, A., Martin, K., & Leppla, N. (2012). Citrus pests. Department of Entomology, University of Florida; Identification Technology Program, CPHST, PPQ, APHIS, USDA. Retrieved July 13, 2024, from https://idtools.org/citrus_pests/
Hoshino, T., Masaki, T., & Nishimoto, M. (2011). Illustrated sedges of Japan. Heibonsha Ltd. [in Japanese]
Korea National Arboretum. (2022). Checklist of vascular plants in Korea (native plants). Korea National Arboretum. [in Korean]
Mishra, S., Tripathi, A., Tripathi, D. K., & Chauhan, D. K. (2015). Role of sedges (Cyperaceae) in wetlands, environmental cleaning and as food material: Possibilities and future perspectives. Plant–Environment Interaction, 1(1), 327–338.
National Institute of Biological Resources (NIBR). (2024). National list of species of Korea. National Institute of Biological Resources. Retrieved January 30, 2024, from https://kbr.go.kr/
Park, S.-H., Lee, Y.-M., Kim, H.-J., Yang, J., Jang, C.-S., Lee, K.-H., Lee, J., Han, J.-S., Jeong, K., Son, D., Lee, D.-H., Joo, M.-J., Sun, E.-M., Shin, C., Choi, K., Oh, S.-H., Chang, K.-S., Jung, S.-Y., & Ji, S.-J. (2016). Illustrated Cyperaceae of Korea. Korea National Arboretum. [in Korean]
Sarnat, E. M. (2008, December 4). PIAkey: Identification guide to ants of the Pacific Islands (2.0 ed., Lucid v. 3.4). USDA/APHIS/PPQ Center for Plant Health Science and Technology; University of California, Davis. Retrieved July 13, 2024, from http://idtools.org/id/ants/pia/
Wäldchen, J., Wittich, H. C., Rzanny, M., Fritz, A., & Mäder, P. (2022). Towards more effective identification keys: A study of people identifying plant species characters. People and Nature, 4(6), 1603–1615.
Wang, S. Q., Dong, X. Y., Ye, L., Wang, H. F., & Ma, K. P. (2023). Flora of Northeast Asia. Plants, 12(12), 2240.
Winterton, S. L., Scher, J. L., Burnett, J., & Redford, A. J. (2018). Aquarium and pond plants of the world (3rd ed.). USDA APHIS Identification Technology Program (ITP); California Department of Food and Agriculture. Retrieved July 13, 2024, from https://idtools.org/appw/

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