Development of an image-assisted interactive key to Lamiaceae in Korea

Yeonju Son

Department of Biology
The Graduate School of Sungshin University

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Yeonju Son

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Yeonju Son

Submitted to Department of Biology

Approved as to style and content :

Thesis Advisor ....

Committee Chairman ....

Committee member 이 재원

The Graduate School of Sungshin University

ABSTRACT

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Despite the advancements in techniques for species identification, morphology–based classification remains essential in various research fields. Lamiaceae, the sixth largest family of angiosperms, is widely used for medicinal and ornamental purposes and is a familiar taxonomic group

in Korea. In this study, we reviewed 166 taxa and 165 morphological characters of Korean Lamiaceae, selecting 85 taxa and summarizing them into 56 key characters. Based on this data, we developed an interactive identification key using Lucid Central Builder v4.0, enabling non-specialists to quickly identify Korean Lamiaceae plants in the field based on observed characteristics (Access URL: http://amborella.net/LamiaceaeProject/02-KoreanLamiaceae/korean_lamiaceae_interactive_key_player.html).

Although the interactive key created in this study is limited to native Korean Lamiaceae, it has the potential to expand to neighboring countries such as Japan and China. This expansion would facilitate the identification of diverse Lamiaceae taxa and provide a foundational resource for studying taxonomically and geographically related groups. Moreover, it could contribute to resolving cross-border inconsistencies in classification.

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Chapter 1. Introduction

1.1 Importance of plant identification and limitations of conventional keys in biodiversity studies

The accurate identification of plant species is a critical foundation in biodiversity research, conservation, and sustainable bio−resources management (Oliver et al. 2024). It plays an essential role in identifying the members of an ecosystem, providing a basis for studying their evolution and developing strategies to conserve plant diversity. In general, accurate species identification becomes more challenging and important in dynamic biodiversity areas where high endemism and complex plant interactions are common. Plant identification is central to various scientific fields, influencing everything from ecology and biogeography to pharmacology and agriculture (Grenié et al. 2022; Kattge et al. 2011). Furthermore, accurate identification contributes to the reliability of molecular databases used for species conservation and ecological studies, thereby supporting quality control in these databases (Dunn 2003; Flannery 2001).

Traditional dichotomous keys, which date back more than 300 years (Griffing 2011), are a widely employed tool for species identification, relying on a sequential selection process where users make binary choices based on morphological characters. While highly valuable in botany and its applications, dichotomous keys have notable limitations. One significant challenge is their reliance on a fixed decision-making path, making accurate identification heavily dependent on each choice. This inflexibility often leads to misidentification if an incorrect choice is made at any stage. This fixed sequence can also prevent accurate identification in taxonomically complex families such as Lamiaceae, where many species exhibit overlapping morphological features. The Lamiaceae family, for example, has undergone numerous classification revisions (Bentham 1876; Briquet 1895-1897; Harley 2004) and is characterized by significant morphological similarities among closely related species. These challenges highlight the need to re-evaluate traditional plant identification methods, particularly given the increasing demand for precise data in biodiversity studies.

In addition to accuracy, traditional keys lack flexibility, often failing to account for morphological diversity within taxa such as the Lamiaceae, whose classification has significantly changed with advances in molecular phylogenetics (Li et al. 2016; Wagstaff and Olmstead 1997). As the scope of biodiversity research has expanded, the last decade has shown a need for new tools that can incorporate this complexity and make it easier to apply in the field of biodiversity research.

1.2 Online interactive keys as a solution

Online interactive keys have become powerful tools in species identification, offering flexibility and accessibility that traditional dichotomous keys lack (Murguía-Romero et al. 2021). Conventional dichotomous keys require a step-by-step sequence, often making the identification process laborious and error-prone, especially for large and complex plant families like the Lamiaceae. Interactive keys address these limitations by allowing users to select characters in any order, providing a more user-friendly approach that accommodates a broader range of morphological characters and reduces the chance of misidentification (Dallwitz 2011). This feature makes interactive keys valuable for users with varying levels of experience, especially for families with significant morphological diversity.

The development of interactive keys spans several decades, beginning with early computer−assisted keys introduced in the 1960s as a solution to traditional keys' limitations (Goodall 1968). In the 1970s, multi−access keys emerged as a further improvement, allowing users to select multiple characters simultaneously, enhancing adaptability to diverse morphological characters (Morse 1971; Pankhurst and Aitchison 1975). One of the most influential systems was DELTA (Description Language for Taxonomy) (Dallwitz 1993). DELTA provided a framework for creating flexible, data−rich keys and enabled taxonomists to input detailed morphological data in a standardized format, facilitating computerized identification and multi−access querying.

Several other interactive key systems were developed with unique features following DELTA to cater to different user needs. Lucid (Norton et al. 2000) is known for its user−friendly interface and versatility, allowing users to identify species based on chosen characters rather than a fixed structure. ActKey (Brach and Song 2005) and Linnaeus NG (Doorenweerd et al. 2014) further expanded multi−access keys' flexibility, tailoring systems to specific taxonomic groups and reaching broader audiences, from researchers to educators. More recent software, including Frida (Martellos and Nimis 2015) and Clavis (Koch et al.

2022), has focused on accessibility for non–specialists while retaining the depth required by experts.

Modern interactive keys have significantly improved taxonomic identification, reducing errors by allowing users to change selected characters without restarting the process. This error–tolerance feature is particularly valuable for complex plant groups like Lamiaceae, where minor character differences can lead to various identifications. In addition, many interactive keys now include visual aids and explanations of technical terms, making them accessible to both experts and non–specialists and bridging the gap between technical knowledge and practical identification skills (Dallwitz 2011; Zuquim et al. 2017). Moreover, interactive keys support the direct input of observed quantitative data, such as leaf length and petal width, which is essential for distinguishing closely related species in morphologically diverse families like Lamiaceae (Bittrich et al. 2012).

Identifying species within a family using the traditional dichotomous key is based on the path that follows the key that distinguishes the genera and the key that distinguishes the species. The characters for constructing an interactive key system start from unifying the characters included in these two hierarchical dichotomous keys. Therefore, the main task for developing an interactive key for a specific family is to integrate the characters that distinguish the genus and the characters that distinguish the species and to adjust the characters and character states from the same perspective.

As digital technology advances, online and mobile versions of interactive keys facilitate the sharing and updating taxonomic data in real-time, particularly relevant in biodiversity research where new species are continually discovered (Grenié et al. 2022). Despite their advantages, interactive keys require high-quality data and frequent updates to remain accurate. The quality of an interactive key depends on comprehensive input data and regular updates to reflect new taxonomic insights.

1.3 Lamiaceae in Korea

The Lamiaceae L. (*sensu lato*), or mint family, is ecologically and economically significant due to its wide distribution and species diversity. Globally, it is one of the largest flowering plant families, containing approximately 226 genera and around 8,210 species (Catalogue of Life 2001). Some members of the Lamiaceae family are highly valuable for their aromatic properties and are used worldwide in culinary, medicinal, and horticultural applications (Judd 2016). With square stems, opposite leaves, and bilabiate flowers, this family (*sensu stricto*) is traditionally recognizable even to non-specialists (Harley 2004). Despite these distinctive features, its extensive morphological diversity poses challenges for accurate identification and classification.

Family criteria of Lamiaceae have recently been expanded based on global molecular phylogenetic studies (Li et al. 2016; Li 2017). Historically, the taxonomy of this family was based primarily on morphological characters, with early systems focusing on floral structures (Bentham and Hooker 1876; Briquet 1895-1897). Molecular phylogenetic studies based on DNA sequencing have shed light on the phylogeny and evolution of the Lamiaceae, which has allowed us to confirm the monophyly of the Lamiaceae and more clearly identify the subfamilies. Since Wagstaff and Olmstead used chloroplast *rbcL* sequences to identify four subfamilies (Caryopteridoideae, Chloanthoideae, Viticoideae, and Symphoremataceae), subsequent studies expanded this classification, incorporating genera previously classified under Verbenaceae, such as *Callicarpa* and *Vitex* (Bendiksby et al. 2011; Li et al. 2016; Wagstaff et al. 1998; Wagstaff and Olmstead 1997), now recognized as part of Lamiaceae *sensu lato*.

In the Republic of Korea, two government agencies, the National Institute of Biological Resources and the Korea National Arboretum, periodically update and release the national list of plant taxa on the Internet: the Checklist of Vascular Plants in Korea (after this, CVPK; http://www.nature.go.kr/kpni/index.do) and the National Species List of Korea (after this, NSLK; https://species.nibr.go.kr/index.do), respectively. However, these do not correspond precisely due to the different views of the botanists involved in these works and the delayed updates of new species and new taxon records in the country. The Lamiaceae part of the Flora of Korea (after this, FL) has recently been published (Flora of Korea 2018), and the latest version of the National Species List reflects this.

Adopting a recent classification system (Li 2017) and two national lists, CVPK and NSLK, the Lamiaceae *sensu lato* in the Republic of Korea is represented by six subfamilies, 32 genera, and approximately 113–117 taxa (Korea National Arboretum and The Plant Taxonomic Society of Korea 2003; National Institute of Biological Resources 2018). Key genera include *Scutellaria*, *Elsholtzia*, *Clinopodium*, and *Isodon*, which display significant species richness, with *Scutellaria* containing 16~17, *Elsholtzia* 10~13, *Clinopodium* 7~8, and *Isodon* 5~7 taxa, respectively. The plants included in these genera are related to various ecosystem studies and traditional Korean medicine.

1.4 Objectives of this study

This study aims to develop an interactive online key to identify Korean Lamiaceae species by incorporating characters distinguishing genera and species in the family. By doing so, the research aims to enhance the accuracy and accessibility of species identification within this taxonomically complex family. This tool will assist a wide range of users, such as taxonomists, conservationists, educators, and the general public, in accurately identifying native Korean Lamiaceae species. The study will contribute to the conservation of biodiversity and the utilization of biological resources at the national level by contributing to the easy and straightforward identification of species of Lamiaceae as a particular taxonomic group within a single country while also contributing to public awareness of plant biodiversity.

Chapter 2. Materials and Methods

2.1 Selection of taxa

The Korean Lamiaceae taxa included in this study were selected primarily by comparing two national databases, the CVPK (http://www.nature.go.kr/kpni/index.do; updated on January 29, 2024) from the Ministry of Environment, National Institute of Biological Resources, and the NSLK (https://species.nibr.go.kr/index.do; updated on November 1, 2023) from the Korea Forest Service, National Arboretum, as well as the list from the FL (Flora of Korea 2018), and the most recent literature-based taxonomic organization of scientific names in the World Flora Online (World Flora Online 2021) (after this, WFO). Taxa were also referenced from recent taxonomic studies of the genera in Korea and papers reporting newly discovered or unrecorded species within each genus.

The taxa and their scientific names included in this study were selected according to the following criteria (Table 1):

1. The target taxa of this study are those native to the Korean Peninsula, excluding North Korea (e. g., *Stachys oblongifolia* Benth. Distributed in North Korea is excluded).

2. Cultivated and naturalized plants were excluded, except those that have been naturalized for a long time and have become established (e. g., *Salvia officinalis* L.).
3. Albino−type variants (whitish individuals) frequently found in Lamiaceae were excluded (e. g., *Scutellaria indica* L. var. *alba* S. T. Kim & S. T. Lee).
4. Only taxa that could be confirmed with all the characters necessary to construct the interactive key from type specimens or at least one voucher specimen were included.
5. If different scientific names are used for a taxon in the CVPK and NLSK lists, and if one of their names is accepted by the WFO, then that name is used (e. g.. *Pogostemon stellatus* (Lour.) Kuntze).
6. For infraspecific taxa with broad character variability or characters challenging to confirm, taxa were recognized at the species level to avoid inconsistencies in recognition (e. g., *Elsholtzia splendens* Nakai ex F.Maek. var. *hallasanensis* (Y. N. Lee) M. Kim were recognized as species level; this variety is not recognized).
7. While the criteria mentioned above were generally applied for recognizing taxa within genera, in some cases, the author's

taxonomic recognition and perception of species were also applied (e. g., *Stachys oblongifolia* Benth.).

2.2 Selection of characters

The morphological characters and character states included in this study were primarily selected based on those included in the literature and observations of type (if available) and voucher specimens (Table 2). FL (Park et al. 2018) was a major literature included, and references to taxonomic studies on newly identified or unrecorded species in each genus were also included. Determination of character states was supplemented by examining voucher specimens for characters absent from the literature. If the character status of each category was unclear or overlapped, the trait status was marked as multiple. When character state expression varied among taxa, they were standardized at the researcher's discretion (e. g., inflorescence type, number of corolla lobes). For quantitative characters with a range (e. g., plant height), the range was followed if it was included in the literature, and if a single number was recorded, a range of ±10% was given centered on it. This was also confirmed in the type specimen or the voucher specimen selected for this study. A total of 165 characters examined, organized in this manner, were selected based on the following criteria.

1. Characters that could not clearly distinguish between or within genera were excluded.
2. Redundant characters identifying the same taxa were removed (e. g., petiole length of basal leaves).
3. Characters challenging to assess in the field were excluded (e. g., biennial growth, protandrous).
4. Subjective characters that might vary by observer perception were excluded (e. g., fragrance, leaf color).
5. Characters with significant variability due to environmental factors were excluded (e. g., flowering period).

All characters and character states are illustrated to facilitate user-friendly decisions in each interactive identification step (Supp. appendix

2.3 Voucher specimen

To construct a clear taxon X character matrix, only taxa confirming their characters from type specimens or a designated voucher specimen for this research were included (Supp. Table 1). A representative voucher specimen for this study was assigned to each taxon based on observation of all available specimens and confirmation of characters described in the literature. Their scanned images were incorporated into the interactive key system to facilitate identification and confirmation of identified taxa. For characters that could not be confirmed from the literature, character states were extracted by direct observation of the type speciemens or a voucher specimen. The list of characters was checked and refined on the basis of specimen comparisons.

Most of the voucher specimens were selected from specimens stored in the herbaria of Sungshin Women's University (SWU) and the Korea National Arboretum (KH), and some were selected from specimens stored in the herbarium of Sungkyunkwan University (SKK), Chonbuk National University (JNU), and the Temperate and Subtropical Forest Research Institute of the Korea Forest Research Institute (WFRC).

2.4 Software used for interactive key

Based on the constructed taxon X character matrix, a web-based interactive key system was constructed using the Lucid Central Builder (v.4.0; Lucidcentral 2001), making it accessible to both specialists and non-specialists by creating a user-friendly website interface. In each taxon, images of the type specimen (if available), at least one voucher specimen, and the type literature including the original description were included in the system.

Chapter 3. Results

3.1 Taxa of Lamiaceae used in this study

Based on specific selection criteria, this interactive key for the Korean Lamiaceae encompasses a total of 82 taxa, 67 species selected from an initial list of 166 taxa (Table 1.) obtained from the CVPK and the NSLK. Among these, 11 taxa endemic to North Korea, such as *Stachys oblongifolia* and *Phlomis koraiensis*, as well as 16 cultivated and introduced taxa, including *Nepeta tenuifolia*, *Perilla frutescens*, *Lavandula angustifolia*, and *Mentha* × *piperita*, were excluded. Additionally, five albino-type variants, including *Prunella asiatica* f. *albiflora* and *Caryopteris incana* f. *candida*, were excluded. Thirty-one taxa (e. g., *Mosla dadoensis*) for which specimens were unavailable for verification were likewise excluded.

The following describes the included taxa, the latest taxonomic research, and the details of the criteria for selecting taxa for each of the 35 selected genera of the Lamiaceae family.

Table 1. List of taxa included in this study according to the recent classification system (Li 2017)

	Scientific name	Korean name
Callicarpoideae	*Callicarpa dichotoma* (Lour.) Raeusch. ex K.Koch	좀작살나무
	Callicarpa japonica Thunb.	작살나무
	Callicarpa japonica Thunb. var. *luxurians* Rehder	왕작살나무
	Callicarpa mollis Siebold & Zucc.	새비나무
Nepetoideae	*Agastache rugosa* (Fisch. & C.A.Mey.) Kuntze	배초향
	Clinopodium chinense (Benth.) Kuntze var. *parviflorum* (Kudô) H.Hara	층층이꽃
	Clinopodium gracile (Benth.) Kuntze	애기탑꽃
	Clinopodium micranthum (Regel) H.Hara	두메층층이
	Clinopodium multicaule (Maxim.) Kuntze	탑꽃
	Clinopodium multicaule (Maxim.) Kuntze var. *shibetchense* (H.Lév.) Melnikov	산층층이
	Dracocephalum argunense Fisch. ex Link	용머리
	Dracocephalum rupestre Hance	벌깨풀
	Elsholtzia angustifolia (Loes.) Kitag.	가는잎향유
	Elsholtzia byeonsanensis M.Kim	변산향유
	Elsholtzia ciliata (Thunb.) Hyl.	향유
	Elsholtzia minima Nakai	좀향유
	Elsholtzia splendens Nakai ex F.Maek.	꽃향유
	Glechoma grandis (A. Gray) Kuprian.	긴병꽃풀
	Isodon excisus (Maxim.) Kudô	오리방풀
	Isodon inflexus (Thunb.) Kudô	산박하
	Isodon inflexus (Thunb.) Kudô var. *canescens* (Nakai) Kudô	털산박하
	Isodon japonicus (Burm.f.) H.Hara	방아풀
	Isodon serra (Maxim.) Kudô	자주방아풀
	Lycopus charkeviczii Prob.	산쉽싸리
	Lycopus coreanus H.Lév.	개쉽싸리
	Lycopus lucidus Turcz. ex Benth.	쉽싸리
	Lycopus lucidus Turcz. ex Benth. var. *hirtus* Regel	큰쉽싸리
	Lycopus maackianus (Maxim. ex Herder) Makino	애기쉽싸리
	Lycopus uniflorus Michx.	털쉽싸리
	Meehania urticifolia (Miq.) Makino	벌깨덩굴
	Mentha canadensis L.	박하
	Mosla chinensis Maxim.	가는잎산들깨
	Mosla dianthera (Buch.-Ham. ex Roxb.) Maxim.	쥐깨풀
	Mosla japonica (Benth. ex Oliv.) Maxim	산들깨
	Mosla scabra (Thunb.) C.Y.Wu & H.W.Li	들깨풀
	Nepeta cataria L.	개박하
	Prunella intermedia Link	갈래꿀풀

Table 1. (Continued)

	Scientific name	Korean name
Nepetoideae	*Prunella vulgaris* L. subsp. asiatica (Nakai) H.Hara	꿀풀
	Salvia chanryoenica Nakai	참배암차즈기
	Salvia japonica Thunb.	둥근배암차즈기
	Salvia plebeia R.Br.	배암차즈기
	Thymus quinquecostatus Čelak.	백리향
Viticoideae	*Vitex negundo* L.	좀목형
	Vitex rotundifolia L.f.	순비기나무
Agugoideae	*Ajuga decumbens* Thunb.	금창초
	Ajuga multiflora Bunge	조개나물
	Ajuga spectabilis Nakai	자란초
	Amethystea caerulea L.	개차즈기
	Caryopteris incana (Thunb. ex Houtt.) Miq.	층꽃나무
	Clerodendrum trichotomum Thunb.	누리장나무
	Teucrium japonicum Houtt.	개곽향
	Teucrium veronicoides Maxim.	곽향
	Teucrium viscidum Blume	섬곽향
	Teucrium viscidum Blume var. *miquelianum* (Maxim.) H.Hara	덩굴곽향
	Tripora divaricata (Maxim.) P.D.Cantino	누린내풀
Scutellariodeae	*Scutellaria baicalensis* Georgi	황금
	Scutellaria barbata D.Don	참골무꽃
	Scutellaria dependens Maxim.	애기골무꽃
	Scutellaria guilielmii A.Gray	날개골무꽃
	Scutellaria indica L.	골무꽃
	Scutellaria indica L. var. *coccinea* S.T.Kim & S.T.Lee	연지골무꽃
	Scutellaria indica L. var. *parvifolia* (Makino) Makino	좀골무꽃
	Scutellaria indica L. var. *tsusimensis* (H.Hara) Ohwi	떡잎골무꽃
	Scutellaria insignis Nakai	광릉골무꽃
	Scutellaria pekinensis Maxim. var. *alpina* (Nakai) H.Hara	수골무꽃
	Scutellaria pekinensis Maxim. var. *maxima* S.T.Kim & S.T.Lee	왕골무꽃
	Scutellaria pekinensis Maxim. var. *transitra* (Makino) H.Hara	산골무꽃
	Scutellaria pekinensis Maxim. var. *ussuriensis* (Regel) Hand.−Mazz	호골무꽃
	Scutellaria strigillosa Hemsl.	참골무꽃
	Scutellaria tuberifera C.Y.Wu & C.Chen	제주골무꽃
Lamioideae	*Galeopsis bifida* Boenn	털향유
	Lagopsis supina (Stephan) Ikonn.−Gal. ex Knorring	흰꽃광대나물
	Lamium album L. subsp. *barbatum* (Siebold & Zucc.) Mennema	광대수염
	Lamium amplexicaule L.	광대나물
	Lamium purpureum L.	자주광대나물
	Lamium takesimense Nakai	섬광대수염
	Leonurus japonicus Houtt.	익모초
	Leonurus macranthus Maxim.	송장풀
	Phlomis umbrosa Turcz.	속단
	Pogostemon stellatus (Lour.) Kuntze	물꼬리풀
	Pogostemon yatabeanus (Makino) Press	전주물꼬리풀
	Stachys riederi Cham. var. *japonica* (Miq.) H.Hara	석잠풀

3.1.1 *Callicarpa*

The taxonomic status and identity of some taxa in *Callicarpa* remain subjects of debate. *C. japonica* var. *taquetii* was initially described as a variety of *C. japonica*, with occurrences reported on Jeju Island, Bogil Island, and Gyeonggi Province (Nakai 1922). However, the specimen collected from Gyeonggi was confirmed to be from a planted individual. Afterwards, researchers classified *C. japonica* var. *taquetii* as a developmental variant exhibiting a lack of stability based on RAPD analysis (Kim and Song 1999). Since most prior studies have primarily focused on morphological characteristics, further research at the molecular level is necessary to resolve its taxonomic position (Lee 2021).

Similarly, *C. mollis* var. *microphylla* was initially described based on morphological distinctions from *C. mollis* (Siebold and Zuccarini 1846). Further research differentiated varieties based on leaf length (Nakai 1922). However, due to the high degree of morphological variability across different habitats, its taxonomic status requires additional investigation (Lee 2021). *C. mollis* var. *chejuensis*, first described as a new taxon (Chung and Kim 1989), was later synonymized with other taxa following RAPD analysis (Kim and Song 1999).

The introgressive hybrid taxon, a result of natural hybridization between C*. japonica* and *C. mollis*, was recognized in 2003 (Tsukaya et al. 2003). *Calicarpa* × *shirasawana* was initially reported from Goheung, Jeollanam-do (Lee, 1928), but it was not studied further until some wild populations were rediscovered. It is now considered a natural hybrid that occurs in disturbed habitats where *C. japonica* and *C. mollis* co-occur (Lee 2021). CVPK and NLSK use different scientific names for a hybrid taxon. Of these two names, only *C. shirasawana* is accepted in the WFO list, so this study can use the name. However, the taxon could not be observed from herbarium sheets, were excluded from this study. Therefore, three taxa were adopted in this study.

Table 2. List of Korean *Callicarpa* and taxa included in this study(bold)

Scientific name	CVPK	NLSK	WFO	Original reference
Callicarpa × s*hiraswana* Makino	개새비나무		Syn. *Callicarpa shirasawana*	Bot. Mag. (Tokyo) 24: 28 (1910)
***Callicarpa dichotoma* (Lour.) Raeusch. ex K.Koch**	좀작살나무	좀작살나무	accepted	Dendrologie 2: 336 (1872)
***Callicarpa japonica* Thunb.**	작살나무	작살나무	accepted	Syst. Veg. (ed. 14) [J.A.Murray] : 153 (1784)
***Callicarpa japonica* Thunb. var. *luxurians* Rehder**	왕작살나무	왕작살나무	accepted	Pl. Wilson. 3: 369 (1916)
Callicarpa japonica var. *taquetii* (L. f.) Nakai		송금나무	unchecked	Fl. Sylv. Kor. 14: 31 (1923)
***Callicarpa mollis* Siebold & Zucc.**	새비나무	새비나무	Syn. *Callicarpa acuminata*	Abh. Math.-Phys. Cl. Königl. Bayer. Akad. Wiss. 4: 155 (1846)
Callicarpa mollis Siebold & Zucc. var. *chejuensis* (Y.H.Chung & H.Kim) M.Kim	제주새비나무		unchecked	Korean Endemic Pl.: 263 (2017)
Callicarpa mollis var. *microphylla* Siebold & Zucc.		좀새비나무	unchecked	Not available
Callicarpa shirasawana Makino		개새비나무	accepted	Bot. Mag. (Tokyo) 24: 28 (1910)

3.1.2 *Agastache*

There is a consensus in all the literature reviewed in this study that the only species of *Agastache* native to Korea is *Agastache rugosa*, with no discrepancies found.

Table 3. List of Korean *Agastache* and a taxon included in this study (bold)

Scientific name	CVPK	NLSK	WFO	Original reference
Agastache rugosa **(Fisch. & C.A.Mey.) Kuntze**	배초향	배초향	accepted	Revis. Gen. Pl. 2: 511 (1891)

3.1.3 *Clinopodium*

C. chinense var. *parviflorum*, *C. gracile*, *C. micranthum*, and *C. multicaule*, which could not be observed from herbarium sheets, were excluded from this study.

Table 4. List of Korean *Clinopodium* and taxa included in this study (bold)

Scientific name	CVPK	NLSK	WFO	Original reference
Clinopodium chinense (Benth.) Kuntze var. *grandiflorum* (Maxim.) H.Hara	꽃층층이꽃	꽃층층이꽃	accepted	J. Jap. Bot. 12: 39 (1936)
Clinopodium chinense **(Benth.) Kuntze var. *parviflorum*** **(Kudô) H.Hara**	층층이꽃	층층이꽃	accepted	J. Jap. Bot. 12: 41 (1936)
Clinopodium chinense (Benth.) Kuntze var. *shibetchense* (H.Lév.) Koidz.		산층층이꽃	Syn. *C. multicaule* var. *shibetchense*	Bot. Mag. (Tokyo) 43: 387 (1929)
Clinopodium chinense var. *glabrescens* (Nakai) H. Hara		푸른산층층이꽃	Syn. *Clinopodium chinense* var. *shibetchense*	Not available
Clinopodium fauriei **(H.Lév. & Vaniot) H.Hara**	개탑꽃	개탑꽃	accepted	J. Jap. Bot. 11: 106 (1935)
Clinopodium gracile **(Benth.) Kuntze**	애기탑꽃	애기탑꽃	accepted	Revis. Gen. Pl. 2: 514 (1891)
Clinopodium micranthum **(Regel) H.Hara**	두메층층이	두메층층이	accepted	J. Jap. Bot. 16: 156 (1940)
Clinopodium multicaule **(Maxim.) Kuntze**	탑꽃	탑꽃	accepted	Revis. Gen. Pl. 2: 515 (1891)
Clinopodium multicaule **(Maxim.) Kuntze var. *shibetchense*** **(H.Lév.) Melnikov**	산층층이꽃		accepted	Novosti Sist. Vyssh. Rast. 47: 106 (2016)

3.1.4 *Dracocephalum*

Since this study includes only naturalized taxa among introduced plants, *D. moldavica*, which was reported as an unrecorded species in 2016, was excluded (Jeong et al. 2016), and the remaining two taxa were adopted.

Table 5. List of Korean *Dracocephalum* and taxa included in this study (bold)

Scientific name	CVPK	NLSK	WFO	Original reference
***Dracocephalum argunense* Fisch. ex Link**	용머리	용머리	accepted	Enum. Hort. Berol. Alt. 2: 118 (1822)
Dracocephalum moldavica L.	향용머리	향용머리	accepted	Sp. Pl. 2: 595 (1753)
***Dracocephalum rupestre* Hance**	벌깨풀	벌깨풀	accepted	J. Bot. 7: 166 (1869)

3.1.5 *Elsholtzia*

The taxonomic status and identity of these taxa remain subjects of debate on *Elsholtzia*. *E. angustifolia* and *E. minima* were described in 1937 and 1915, respectively (Institute of Scientific Research of Manchoukuo 1937; Nakai 1915). Although these two taxa are morphologically distinct, Li and Hedge treated them as synonyms of *E. splendens* and *E. ciliata*, respectively, suggesting further research (Li and Hedge 1994).

E. splendens var. *hallasanensis* was described as a new variety in 2000 (Lee 2000), but it has been reported that clear morphological differences from *E. splendens* are difficult to identify. Additionally, *E. serotina* could not be confirmed with its type specimen and was presumed to be a close relative of *E. splendens* (Jeon and Hong 2006).

Hwang (2005) conducted a molecular analysis comparing ITS, *rpl16*, and *trnH-psbA* DNA sequences(Hwang 2005). Her study suggested that *E. angustifolia*, *E. minima*, and *E. splendens* var. *hallasanensis* should be considered part of the *E. splendens* complex, excluding *E. ciliata*. However, Lee supported the distinct status of *E. angustifolia* and *E. minima* from *E. splendens* and *E. ciliata* (Lee et al. 2011). Additionally, due to the close relationship among *E. splendens*, *E. splendens* var. *hallasanensis*, and *E. springia*, Lee proposed that *E. springia* should be treated as a synonym of *E. splendens* var. *hallasanensis*. Lee further concluded that *E. splendens* var. *hallasanensis* should be treated as a variety, and molecular evidence supports classifying *E. splendens* var. *fasciflora* as a variety.

The studies mentioned above do not include *E. byeonsanensis* and *E. splendens* var. *fasciflora* because they were introduced as a new species and a new variety by Choi and Jin (Choi et al. 2012; Jin et al. 2022), respectively.

The study is based on herbarium specimens deposited at the KH and the SWU. Accordingly, five taxa were selected. Due to differing opinions on the recognition of *E. splendens* var. *fasciflora* and *E. splendens* var. *hallasanensis* as subspecies, only *E. splendens* was treated as a species. Although *E. griffithii* was reported as an unrecorded species (Hong et al. 2021), it was excluded from this study, as only naturalized taxa among introduced plants were included. Due to discrepancies between the classifications recognized by the two institutions, *E. angustifolia* was adopted based on its acceptance in the WFO.

Table 6. List of Korean *Elsholtzia* and taxa included in this study (bold)

Scientific name	CVPK	NLSK	WFO	Original reference
***Elsholtzia angustifolia* (Loes.) Kitag.**	가는잎향유		accepted	Rep. Inst. Sci. Res. Manchoukuo 1: 265 (1937)
***Elsholtzia byeonsanensis* M.Kim**	변산향유	변산향유	Syn. *Elsholtzia splendens* var. *splendens*	Korean J. Pl. Taxon. 42(3): 198 (2012)
***Elsholtzia ciliata* (Thunb.) Hyl.**	향유	향유	accepted	Bot. Not. 1941: 129 (1941)
Elsholtzia griffithii Hook.f.	남방향유	남방향유	accepted	Fl. Brit. India 4: 644 (1885)
Elsholtzia hallasanensis Y.N.Lee		한라꽃향유	Syn. *Elsholtzia ciliata*	Alp. Flow. Korea: 328 (2000)
***Elsholtzia minima* Nakai**	좀향유	좀향유	accepted	Bot. Mag. (Tokyo) 29: 1 (1915)
Elsholtzia saxatilis (Kom.) Nakai ex Kitag.		가는잎향유	Syn. *Elsholtzia serotina*	Rep. Inst. Sci. Res. Manchoukuo 1: 266 (1937).
Elsholtzia serotina Kom.	애기향유	애기향유	accepted	Izv. Glavn. Bot. Sada SSSR 30: 210 (1932)
***Elsholtzia splendens* Nakai ex F.Maek.**	꽃향유	꽃향유	accepted	Bot. Mag. (Tokyo) 48: 50 (1934)
Elsholtzia splendens Nakai ex F.Maek. var. *fasciflora* N.S.Lee, M.S.Chung & C.S.Lee	다발꽃향유	다발꽃향유	unchecked	Korean J. Pl. Taxon. 40: 263 (2010)
Elsholtzia splendens Nakai ex F.Maek. var. *hallasanensis* (Y.N.Lee) M.Kim	한라꽃향유		unchecked	Korean Endemic Pl.: 266 (2017)

3.1.6 *Glechoma*

CVPK and NLSK use different scientific names for a species of *Glechoma* in Korea. There are also discrepancies among domestic publications regarding the accepted taxa. Jang and Lee identified it as *G. longituba* (Jang et al. 2014; Lee 1989). In contrast, Park and Suh recognized it as *G. grandis* (Park 2007; Park 2018a). The Flora of China distinguishes *G. longituba* and *G. grandis* based on differences in calyx length, shape, and the size of calyx teeth (Hedge and Li 2004). When identifying specimens owned by SWU using the key from the Flora of China, most had flowers in the inflorescence that were more than twice the length of the calyx, and the calyx length averaged 6 mm. The calyx lobe tips were closer to being acuminate than awned. Therefore, based on the researcher's judgment, the specimens were identified as *Glechoma grandis*.

Table 7. List of Korean *Glechoma* and a taxon included in this study(bold)

Scientific name	CVPK	NLSK	WFO	Original reference
***Glechoma grandis* (A. Gray) Kuprian.**		긴병꽃풀	accepted	Bot. Zhurn. (Moscow & Leningrad) 33: 237 (1948).
Glechoma longituba (Nakai) Kuprian.	긴병꽃풀		accepted	Bot. Zhurn. (Moscow & Leningrad) 33: 236 (1948)

3.1.7 *Isodon*

Except two taxa(I. *inflexus* var. *microphyllus*, *I. inflexus* var. *transticus*), There is a consensus in all the literature reviewed in this study that five species of Isodon native to Korea. In Ma and Kim (2014), Reseachers reclassified the genus by excluding *I. inflexus* var. *transticus*, introducing new diagnostic characteristics such as high stem hair density, leaf size, and non−glandular trichome characters (Ma and Kim 2014). Similarly, Kim recognizes six taxa within the *Isodon* (Kim 2018).

In this study, following the criterion that taxa with differing opinions on infraspecific classification should be treated at the species level, *I. inflexus* var. *microphyllus* and *I. inflexus* var. *transticus* were grouped under *I. inflexus*. Consequently, the interactive key for this study adopts five taxa.

Table 8. List of Korean *Isodon* and taxa included in this study (bold)

Scientific name	CVPK	NLSK	WFO	Original reference
***Isodon excisus* (Maxim.) Kudô**	오리방풀	오리방풀	accepted	Mem. Fac. Sci. Taihoku Imp. Univ. 2: 133 (1929)
***Isodon inflexus* (Thunb.) Kudô**	산박하	산박하	accepted	Bot. Mag. (Tokyo) 26: 302 (1912)
***Isodon inflexus* (Thunb.) Kudô var. *canescens* (Nakai) Kudô**	털산박하	털산박하	unchecked	Mem. Fac. Sci. Taihoku Imp. Univ. 2: 129 (1929)
Isodon inflexus (Thunb.) Kudô var. *microphyllus* (Nakai) Kudô	영도산박하		unchecked	Mem. Fac. Sci. Taihoku Imp. Univ. 2: 127 (1929)
Isodon inflexus (Thunb.) Kudô var. *transticus* Matsum. & Kudô	긴잎산박하		unchecked	Bot. Mag. (Tokyo) 26: 302 (1912)
***Isodon japonicus* (Burm.f.) H.Hara**	방아풀	방아풀	accepted	Enum. Spermatophytarum Japon. 1: 206 (1948)
***Isodon serra* (Maxim.) Kudô**	자주방아풀	자주방아풀	accepted	Mem. Fac. Sci. Taihoku Imp. Univ. 2: 125 (1929)

3.1.8 *Lycopus*

Two institutions recognized one taxon under different scientific names. Son (2016) noted that the scientific name of *L. coreanus* has been used inconsistently. However, following the original description (Léveillé 1910), the name should be standardized as either *L. coreanus* or *L. cavaleriei*. Since (Henderson 1962) used *L. coreanus* as the accepted name, Son concluded that it is appropriate to adopt *L. coreanus* as the correct name (Son et al. 2016a). Additionally, in the case of the unrecorded species *L. lucidus* var. *hirtus* (Moon et al. 2013), Son initially distinguished it from other *Lycopus* species based on stem and leaf hair density. However, field investigations revealed continuous variation within the same population. Consequently, Son proposed treating *L. lucidus* var. *hirtus* as a synonym of *L. lucidus* (Son et al. 2016b).

This study adopts six taxa, based on herbarium sheets verified at the KH and the SWU. Among the differing classifications, the name *L. coreanus* was selected based on the researcher’ s judgment.

Table 9. List of Korean *Lycopus* and taxa included in this study (bold)

Scientific name	CVPK	NLSK	WFO	Original reference
***Lycopus charkeviczii* Prob.**	산쉽싸리	산쉽싸리	accepted	Sosud. Rast. Sovet. Dal'nego Vostoka 7: 351 (1995)
***Lycopus coreanus* H.Lév.**	개쉽싸리		Syn. *Lycopus uniflorus*	Repert. Spec. Nov. Regni Veg. 8: 423 (1910)
***Lycopus lucidus* Turcz. ex Benth.**	쉽싸리	쉽싸리	accepted	Prodr. (DC.) 12: 179 (1848)
***Lycopus lucidus* Turcz. ex Benth. var. *hirtus* Regel**	큰쉽싸리	큰쉽싸리	accepted	Mém. Acad. Imp. Sci. Saint Pétersbourg, Sér. 7 4: 115 (1861)
***Lycopus maackianus* (Maxim. ex Herder) Makino**	애기쉽싸리	애기쉽싸리	Syn. *Lycopus lucidus* var. *maackianus*	Bot. Mag. (Tokyo) 11: 382 (1897)
Lycopus ramosissimus (Makino) Makino		개쉽싸리	Syn. Lycopus cavaleriei	J. Jap. Bot. 1: 14 (1917)
***Lycopus uniflorus* Michx.**	털쉽싸리	털쉽싸리	accepted	Fl. Bor.-Amer. [Michaux] 1: 14 (1803)

3.1.9 *Meehania*

An albino-type forma, *M. urticifolia* f. *leucantha*, excluded from this study. Therefore, This study adopts one taxon.

Table 10. List of Korean *Meehania* and a taxon included in this study (bold)

Scientific name	CVPK	NLSK	WFO	Original reference
***Meehania urticifolia* (Miq.) Makino**	벌깨덩굴	벌깨덩굴	accepted	Bot. Mag. (Tokyo) 13: 159 (1899)
Meehania urticifolia f. *leucantha* H. Hara		흰벌깨덩굴	Syn. *Meehania urticifolia*	J. Jap. Bot. 11: 671 (1935)

3.1.10 *Mentha*

Two cultivated varieties, *M. spicata* (Spearmint) and *Mentha* × *piperita* (Peppermint), and a North Korean species, *M. arvensis* var. *barbata* were excluded. CVPK and NLSK use different scientific names for a species of *Mentha* in Korea. Of these two names, only *M. canadensis* is accepted in the WFO list, so this study used the name.

Table 11. List of Korean *Mentha* and a taxon included in this study (bold)

Scientific name	CVPK	NLSK	WFO	Original reference
Mentha arvensis L. var. *piperascens* Malinv. ex Holmes	박하		Syn. *Mentha canadensis*	Pharm. J. Trans. 13: 381 (1882)
***Mentha canadensis* L.**		박하	accepted	Sp. Pl. 2: 577 (1753)
Mentha spicata L.	녹양박하	녹양박하	accepted	Sp. Pl. 2 : 576 (1753)
Mentha × *piperita* L.	페퍼민트	페퍼민트	accepted	Sp. Pl. 2 : 576 (1753)
Mentha arvensis var. *barbata*	털박하		Syn. *Mentha canadensis*	Lin. Fl. Kor. : 955 (1996)

3.1.11 *Mosla*

Jang et al. (2022) reported *Mosla dadoensis* as a new species (Jang et al. 2022), but no specimens of this species were available for verification at KH and SWU. Furthermore, specimens of *M. japonica* f. *thymolifera* and *M. punctulata* were also unavailable. Consequently, this study organizes the *Mosla* into a total of four taxa.

Table 12. List of Korean *Mosla* and taxa included in this study (bold)

Scientific name	CVPK	NLSK	WFO	Original reference
***Mosla chinensis* Maxim.**	가는잎산들깨	가는잎산들깨	accepted	Bull. Acad. Imp. Sci. Saint-Pétersbourg, sér. 3 29: 177 (1883)
Mosla dadoensis K.K.Jeong, M.J.Nam & H.J.Choi	다도해산들깨	다도해산들깨	unchecked	PhytoKeys 208: 188 (2022)
***Mosla dianthera* (Buch.-Ham. ex Roxb.) Maxim.**	쥐깨풀	쥐깨풀	accepted	Bull. Acad. Imp. Sci. Saint-Pétersbourg, sér. 3 20(3): 457 (1875)
Mosla dianthera (Buch.-Ham. ex Roxb.) Maxim. var. *nana* (H.Hara) Ohwi	털쥐깨	털쥐깨풀	Syn. *Mosla dianthera*	Fl. Jap., revised ed., [Ohwi] : 780 (1965)
***Mosla japonica* (Benth. ex Oliv.) Maxim**	산들깨	산들깨	accepted	Bull. Acad. Imp. Sci. Saint-Pétersbourg, sér. 3 20: 461 (1875)
Mosla japonica (Benth. ex Oliv.) Maxim. f. *thymolifera* (Makino) T.Yamaz. & Murata	섬쥐깨풀		Syn. *Mosla japonica*	Fl. Jap. (Iwatsuki et al., eds.) 3a: 287 (1993)
Mosla japonica var. *thymolifera* (Makino) Kitam.		섬쥐깨풀	unchecked	Not available
Mosla punctulata (J. F. Gmel.) Nakai		들깨풀	Syn. *Mosla scabra*	Bot. Mag. (Tokyo) 42: 475 (1928)
***Mosla scabra* (Thunb.) C.Y.Wu & H.W.Li**	들깨풀		accepted	Acta Phytotax. Sin. 12: 230 (1974)

3.1.12 *Nepeta*

N. manchuriensis and *N. multifida* are native to North Korea, while *N. tenuifolia* is a cultivated species originating from China. Accordingly, this study organizes the *Nepeta* into a single taxon."

Table 13. List of Korean *Nepeta* and a taxon included in this study (bold)

Scientific name	CVPK	NLSK	WFO	Original reference
***Nepeta cataria* L.**	개박하	개박하	accepted	Sp. Pl. 2: 570 (1753)
Nepeta tenuifolia Benth.	형개	형개	accepted	Labiat. Gen. Spec. : 468 (1834)
Nepeta multifida L.	개형개	개형개	accepted	Sp. Pl. 2 : 572 (1753)
Nepeta manchuriensis S.Moore	간장풀	간장풀	accepted	J. Bot. 18 : 5 (1880)

3.1.13 *Perilla*

P. frutescens, *P. frutescens* var. *crispa*, and *P. frutescens* var. *purpurascens* are all cultivated varieties. Additionally, specimens of *P. citriodora*, *P. hirtella*, and *P. frutescens* var. *hirtella* could not be verified at the KH or the SWU. As a result, the interactive key developed for this study includes no taxa for the *Perilla*.

Table 14. List of Korean *Perilla* and a taxon included in this study (bold)

Scientific name	CVPK	NLSK	WFO	Original reference
Perilla citriodora (Makino) Nakai	섀들깨	섀들깨	Syn. *Perilla frutescens* var. *hirtella*	Perilla citriodora (Makino) Nakai
Perilla frutescens (L.) Britton var. *hirtella* (Nakai) Makino	털들깨		accepted	Fl. Japan (ed. 2) [Makino & Nemoto]: 218 (1931)
Perilla frutescens var. *purpurascens* (Hayata) H. W. Li		야생소엽	Syn. *Perilla frutescens* var. *frutescens* (들깨)	Acta Bot. Yunnan. 13(3): 350 (1991).
Perilla hirtella Nakai		털들깨	Syn. *Perilla frutescens* var. *hirtella*	Bot. Mag. (Tokyo) 31: 286 (1917).
Perilla frutescens (L.) Britton	들깨	들깨	accepted	Mem. Torrey Bot. Club 5 : 277 (1894)
Perilla frutescens (L.) Britton var. *crispa* (Benth.) W.Deane	소엽	소엽	accepted	Rhodora 25(291) : 40 (1923)

3.1.14 *Prunella*

P. vulgaris, P. vulgaris was first described in 1753 (Linnæus 1753), and in the Coloured Flora of Korean Plants, the erect main stem without stolons and the short new shoots attached to the base of the main stem are identified as distinguishing characteristics of *P. vulgaris* (Lee 2003). In the Flora of China, *P. vulgaris* is described as having a heavily branched base with sparse or nearly absent long hairs (Hedge and Li 2004), while in the FL, *P. vulgaris* subsp. *asiatica* is described as typically having well-developed stolons, with long hairs either sparsely or densely distributed, and occasional crisped hairs (Kim and Park 2018b). However, all *P. vulgaris* specimens from the KH and SWU collections that were available for examination had long hairs that were either sparsely or densely distributed and also displayed crisped hairs. Additionally, when considering environmental and individual variations, distinguishing based on the presence of stolons and branching at the base was determined to be unreliable for identifying *P. vulgaris*. And study excludes albino form from infraspecific classification (*P. asiatica* f. *albiflora* and *P. vulgaris* subsp. *asiatica* f. *leucocephala*) were excluded. Therefore, this study adopted only two taxa, *P. vulgaris* subsp. *asiatica* and *P. intermedia*.

Table 15. List of Korean *Prunella* and taxa included in this study (bold)

Scientific name	CVPK	NLSK	WFO	Original reference
Prunella asiatica Nakai		꿀풀	Syn. *Prunella vulgaris* subsp. *asiatica*	Rep. Veg. Kami-Kochi 29, No. 243 (1928).
***Prunella intermedia* Link**	갈래꿀풀		Syn. *Prunella* × *intermedia*	Ann. Naturgesch. 1: 32 (1791)
Prunella pinnatifida Pers.		갈래꿀풀	Syn. *Prunella* x *intermedia*	Syn. Pl. [Persoon] 2(1): 137 (1806).
Prunella vulgaris L.	두메꿀풀	두메꿀풀	accepted	Sp. Pl. 2: 600 (1753)
***Prunella vulgaris* L. subsp. *asiatica* (Nakai) H.Hara**	꿀풀		accepted	Enum. Spermatophytarum Japon. 1: 220 (1948)
Prunella vulgaris L. subsp. *asiatica* (Nakai) H.Hara f. *leucocephala* K.Ohashi, H.Ohashi & Yonek.	흰꿀풀		unchecked	J. Jap. Bot. 86(6) : 371 (2011)
Prunella asiatica f. *albiflora* (Nakai) Kitag.		흰꿀풀	Syn. *Prunella vulgaris* subsp. *asiatica*	Lin. Fl. Manshur. : 384 (1939)

3.1.15 *Salvia*

As *S. miltiorrhiza*, *S. officinalis*, and *S. splendens* are cultivated species, they were excluded from the interactive key. Accordingly, this study adopts three taxa, including *S. japonica*, for the interactive key.

Table 16. List of Korean *Salvia* and taxa included in this study (bold)

Scientific name	CVPK	NLSK	WFO	Original reference
Salvia chanryoenica **Nakai**	참배암차즈기	참배암차즈기	accepted	Bot. Mag. (Tokyo) 23: 190 (1909)
Salvia japonica **Thunb.**	둥근배암차즈기	둥근배암차즈기	accepted	Syst. Veg. (ed. 14) [J.A.Murray] 14: 72 (1784)
Salvia plebeia **R.Br.**	배암차즈기	배암차즈기	accepted	Prodr. Fl. Nov. Holland. 1: 501 (1810)
Salvia miltiorrhiza Bunge	단삼		accepted	Enum. Pl. China Bor. : 50 (1835)
Salvia officinalis L.	세이지	살비아	accepted	Sp. Pl. 1 : 23 (1753)
Salvia splendens Sellow ex Nees	깨꽃		accepted	Flora 4 : 300 (1821)
Salvia splendens Sellow ex Wied-Neuw.		깨꽃	unckecked	Not available

3.1.16 *Thymus*

Kim (2023) reported that an analysis of the chloroplast DNA trnL-trnF and psbA-trnH intergenic spacer regions did not reveal any molecular differences between the two taxa (Kim et al. 2003). Similarly, Park only recognized a single taxon of Thymus (Park 2018a). Therefore, based on the researcher's judgment, this study adopts a single taxon of Thymus for the interactive key.

Table 17. List of Koean *Thymus* and taxa included in this study (bold)

Scientific name	CVPK	NLSK	WFO	Original reference
***Thymus quinquecostatus* Čelak.**	백리향	백리향	accepted	Oesterr. Bot. Z. 39: 263 (1889)
Thymus quinquecostatus Čelak. var. *magnus* (Nakai) Kitam.	섬백리향	섬백리향	unchecked	Acta Phytotax. Geobot. 14: 118 (1952)

3.1.17 *Vitex*

CVPK and NLSK use different scientific names for a species of *Vitex* in Korea. Both names have been treated as synonyms of *V. negundo* in the WFO. Based on the researcher's judgment, the interactive key developed for this study organizes two taxa.

Table 18. List of Korean *Vitex* and taxa included in this study (bold)

Scientific name	CVPK	NLSK	WFO	Original reference
Vitex negundo L. var. *incisa* (Lam.) C.B.Clarke	좀목형		Syn. *Vitex negundo*	Fl. Brit. Ind. 4: 584 (1885)
Vitex negundo var. *heterophylla* (Franch.) Rehder		좀목형	Syn. *Vitex negundo*	J. Arnold Arbor. 28(2): 258 (1947).
***Vitex rotundifolia* L.f.**	순비기나무	순비기나무	Syn. *Vitex trifolia* subsp. *litoralis*	Suppl. Pl.: 294 (1781)

3.1.18 *Ajuga*

A. multiflora f. *rosea*. *A. nipponensis*, an unrecorded species reported in 2014 (Kim et al. 2013), was excluded from this study as it is not considered a naturalized species, despite having been introduced long ago. *A. multiflora* f. rosea is recognized by Kim (2014), but was not mentioned by other literature (Flora of Korea 2018; Kim 2014). As there are differing opinions between the two institutions regarding *A. multiflora* f. rosea, it was treated at the species level according to the classification standard. Therefore, this study organizes the *Ajuga* into three taxa for the interactive key.

Table 19. List of Korean *Ajuga* and taxa included in this study

Scientific name	CVPK	NLSK	WFO	Original reference
Ajuga decumbens **Thunb.**	금창초	금창초	accepted	Syst. Veg. (ed. 14) [J.A.Murray]: 525 (1784)
Ajuga multiflora **Bunge**	조개나물	조개나물	accepted	Enum. Pl. China Bor. [A.A. von Bunge]: 51 (1833)
Ajuga multiflora f. *rosea* Y. N. Lee		붉은조개나물	Syn. *Ajuga multiflora* var. *multiflora*	Not available
Ajuga nipponensis Makino	분홍꽃조개나물	분홍꽃조개나물	accepted	Bot. Mag. (Tokyo) 23: 67 (1909)
Ajuga spectabilis **Nakai**	자란초	자란초	accepted	Bot. Mag. (Tokyo) 30: 290 (1916)

3.1.19 *Amethysea*

There is a consensus in all the literature reviewed in this study that the only species of *Amethysea* native to Korea is *Amethystea caerulea*, with no discrepancies found.

Table 20. List of Korean *Amethystea* and a taxon included in this study

Scientific name	CVPK	NLSK	WFO	Original reference
Amethystea caerulea **L.**	개차즈기	개차즈기	accepted	Sp. Pl. 1: 21 (1753)

3.1.20 *Caryopteris*

As *Caryopteris incana* f. *candida* is a abino form, it was excluded from the interactive key following the established criteria, and the genus was organized into a single taxon.

Table 21. List of Korean *Caryopteris* and taxa included in this study

Scientific name	CVPK	NLSK	WFO	Original reference
Caryopteris incana **(Thunb. ex Houtt.) Miq.**	층꽃나무	층꽃나무	accepted	Ann. Mus. Bot. Lugduno-Batavi 2: 97 (1865)
Caryopteris incana f. candida (C.K. Schneid.) H. Hara		흰층꽃나무	Syn. *Caryopteris incana* var. *incana*	Enum. Spermatophytarum Japon. 1: 187 (1948)

3.1.21 *Clerodendrum*

In the FL (Im 2018), only a single taxon, *Clerodendrum trichotomum,* is recognized. However, research conducted in Japan indicates that *C. trichotomum* and *C. trichotomum* var. *esculentum* differ in chromosome number, with 2n = 104 and 2n = 52, respectively (Mizusawa et al. 2019). Furthermore, *C. trichotomum* var. *esculentum* is reported to be native to southern Japan, specifically in the Nansei Islands, which are geographically distant from Korea. According to the CVPK, *C. trichotomum* var. *esculentum* is recorded in Korea in southern regions of Gangwondo and Hwanghaedo, as well as in Jeollanamdo(Geomoondo) and nearby southern islands. A total of 6 verifiable KH specimens exist: one collected in Yeosu, Jeollanamdo, in 1928, and 5 others from cultivated individuals at the National Institute of Forest Science.

Additionally, *C. trichotomum* var*. ferrugineum* is recognized by both institutions. This variety is distinguished from *C. trichotomum* by rust-colored tomentose hairs covering the bracts, leaves, and inflorescence (Hedge and Li 2004). The NLSK lists its native habitat as the southern half of the Korean peninsula. However, only three verified specimens exist: 2 from Gyeongsangnamdo, and one from Gangwondo. Consequently, this study established a criterion to recognize taxa at the species level in cases of taxonomic discrepancy at the infraspecific level. Accordingly, only one taxon, *C. trichotomum,* was adopted.

Table 22. List of Korean *Clerodendrum* and a taxon included in this study (bold)

Scientific name	CVPK	NLSK	WFO	Original reference
***Clerodendrum trichotomum* Thunb.**	누리장나무	누리장나무	accepted	Nova Acta Regiae Soc. Sci. Upsal. 3: 201 (1780)
Clerodendrum trichotomum Thunb. var. *esculentum* Makino	섬누리장나무		Syn. *Clerodendrum trichotomum*	J. Jap. Bot. 1: 29 (1917)
Clerodendrum trichotomum Thunb. var. *ferrugineum* Nakai	털누리장나무	털누리장나무	accepted	Bot. Mag. (Tokyo) 31: 109 (1917)

3.1.22 *Teucrium*

No discrepancies across the literature reviewed in this study. However, a specimen identical to the one described in the FL (Park 2018c) for *T. viscidum* could not be observed from herbarium sheets, Therefore, based on the researcher' s judgment, the *Teucrium* has been classified into three taxa, excluding *T. viscidum*.

Table 23. List of Korean *Teucrium* and taxa included in this study (bold)

Scientific name	CVPK	NLSK	WFO	Original reference
Teucrium japonicum **Houtt.**	개곽향	개곽향	accepted	Nat. Hist. (Houttuyn) 9: 282 (1778)
Teucrium veronicoides **Maxim.**	곽향	곽향	accepted	Bull. Acad. Imp. Sci. Saint-Pétersbourg, sér. 3 23: 388 (1877)
Teucrium viscidum Blume	섬곽향	섬곽향	accepted	Bijdr. Fl. Ned. Ind. 14: 827 (1826)
Teucrium viscidum **Blume var. *miquelianum* (Maxim.) H.Hara**	덩굴곽향	덩굴곽향	accepted	Bot. Mag. (Tokyo) 51: 145 (1937)

3.1.23 *Tripora*

There is a consensus in all the literature reviewed in this study that the only species of *Tripora* native to Korea is *Tripora divaricata*, with no discrepancies found.

Table 24. List of Korean *Tripora* and a taxon included in this study (bold)

Scientific name	CVPK	NLSK	WFO	Original reference
Tripora divaricata (Maxim.) P.D.Cantino	누린내풀	누린내풀	accepted	Syst. Bot. 23: 382 (1998)

3.1.24 *Scutellaria*

four taxa that are native only to North Korea (*S. asperiflora*, *S. moniliorhiza*, *S. tuminensis*, and *S. regeliana*) were excluded. Additionally, *S. indica* var. *alba* was excluded according to the criteria, as it is an albino form of *S. indica*. The cultivated species *S. baicalensis* wasn't excluded since it has become naturalized and widely established, while *S. orthocalyx* , which has not naturalized, was excluded.

Table 25. List of Korean *Scutellaria* and taxa included in this study (bold)

Scientific name	CVPK	NLSK	WFO	Original reference
Scutellaria asperiflora Nakai	다발골무꽃	다발골무꽃	accepted	Bot. Mag. (Tokyo) 35: 194 (1921)
Scutellaria baicalensis **Georgi**	황금	황금	accepted	Reise Russ. Reich. 1: 223 (1775)
Scutellaria barbata **D.Don**	창골무꽃	창골무꽃	accepted	Prodr. Fl. Nepal.: 109 (1825)
Scutellaria dependens **Maxim.**	애기골무꽃	애기골무꽃	accepted	Mém. Acad. Imp. Sci. St.−Pétersbourg, Divers Savans 9 : 217 (1859)
Scutellaria guilielmii **A.Gray**	날개골무꽃	날개골무꽃	unchecked	Proc. Amer. Assoc. Advancem. Sci. 21 : 25 (1872)
Scutellaria indica **L.**	골무꽃	골무꽃	accepted	Sp. Pl. 2 : 600 (1753)
Scutellaria indica **L. var.** ***coccinea*** **S.T.Kim & S.T.Lee**	연지골무꽃	연지골무꽃	Syn. *Scutellaria indica* var. *indica*	Korean J. Pl. Taxon. 24 : 74 (1994)
Scutellaria indica **L. var.** ***parvifolia*** **(Makino) Makino**	좀골무꽃	좀골무꽃	accepted	Iinuma, Somoku−Dzusetsu (ed. 3) : 846 (1912)
Scutellaria indica **L. var.** ***tsusimensis*** **(H.Hara) Ohwi**	떡잎골무꽃	떡잎골무꽃	accepted	Fl. Jap., revised ed., [Ohwi] : 1150 (1965)
Scutellaria insignis **Nakai**	광릉골무꽃	광릉골무꽃	accepted	Bot. Mag. (Tokyo) 29 : 2 (1915)
Scutellaria pekinensis **Maxim. var.** ***alpina*** **(Nakai) H.Hara**	수골무꽃		unchecked	Enum. Spermatophytarum Japon. 1 : 229 (1948)
Scutellaria pekinensis **Maxim. var.** ***maxima*** **S.T.Kim & S.T.Lee**	왕골무꽃	왕골무꽃	unchecked	Korean J. Pl. Taxon. 25 : 28 (1995)
Scutellaria pekinensis **Maxim. var.** ***transitra*** **(Makino) H.Hara**	산골무꽃	산골무꽃	accepted	Enum. Spermatophytarum Japon. 1 : 229 (1948)
Scutellaria pekinensis **Maxim. var.** ***ussuriensis*** **(Regel) Hand.−Mazz**	호골무꽃	호골무꽃	accepted	Acta Horti Gothob. 13 : 339 (1939
Scutellaria strigillosa **Hemsl.**	참골무꽃	참골무꽃	accepted	J. Linn. Soc., Bot. 26 : 297 (1890)
Scutellaria tuberifera **C.Y.Wu & C.Chen**	제주골무꽃	제주골무꽃	accepted	Fl. Yunnan. 1 : 566 (1977)
Scutellaria asperiflora Nakai	다발골무꽃	다발골무꽃	accepted	Bot. Mag. (Tokyo) 35 : 194 (1921)
Scutellaria moniliorhiza Kom.	구슬골무꽃	구슬골무꽃	accepted	Trudy Imp. S.−Peterburgsk. Bot. Sada 25 : 346 (1907)
Scutellaria tuminensis Nakai	두만강골무꽃	두만강골무꽃	accepted	Bot. Mag. (Tokyo) 35 : 198 (1921)
Scutellaria regeliana Nakai	가는골무꽃	가는골무꽃	accepted	Bot. Mag. (Tokyo) 35 : 197 (1921)
Scutellaria indica L. var. *alba* S.T.Kim & S.T.Lee	비바리골무꽃		Syn. *Scutellaria indica* var. *indica*	Korean J. Pl. Taxon. 24 : 74 (1994)
Scutellaria orthocalyx Hand.−Mazz.	소황금	소황금	accepted	Acta Horti Gothob. 9 : 75 (1934)

3.1.25 *Dysophylla*

In cases where there are differences in taxonomic recognition between the CVPK and NLSK, the accepted name in the WFO is followed. So only *Pogostemon stellatus* is accepted in the WFO list, this study organizes *Dysophylla* into zero.

Table 26. List of Korean *Dysophylla* and a taxon included in this study (bold)

Scientific name	CVPK	NLSK	WFO	Original reference
Dysophylla stellata (Lour.) Benth.		물꼬리풀	Syn. *Pogostemon stellatus*	Pl. Asiat. Rar. 1: 30 (1830)
Dysophylla yatabeana Makino		전주물꼬리풀	Syn. *Pogostemon yatabeanus*	Bot. Mag. (Tokyo) 12: 55 (1898)

3.1.26 *Galeopsis*

There is a consensus in all the literature reviewed in this study that the only species of *Galeopsis* native to Korea is *Galeopsis bifida*, with no discrepancies found.

Table 27. List of Korean *Galeopsis* and a taxon included in this study (bold)

Scientific name	CVPK	NLSK	WFO	Original reference
***Galeopsis bifida* Boenn**	털향유	털향유	accepted	Prodr. Fl. Monast. Westphal.: 178 (1824)

3.1.27 *Lagopsis*

There is a consensus in all the literature reviewed in this study that the only species of *Lagopsis* native to Korea is *Lagopsis supina*, with no discrepancies found. This taxon was introduced from abroad, and although it could not be determined if it has naturalized in Korea, it was included in the study as specimens exist in the KH and SWU herbarium sheets.

Table 28. List Korean *Lagopsis* and a taxon included in this study (bold)

Scientific name	CVPK	NLSK	WFO	Original reference
Lagopsis supina (Stephan) Ikonn.-Gal. ex Knorring	흰꽃광대나물	흰꽃광대나물	accepted	Fl. URSS 20: 250 (1954)

3.1.28 *Lamium*

L. purpureum reported as an unrecorded species in Korea (Ji et al. 2012). And it was determined to be a naturalized alien species, not established in the wild. Moreover, *L. album* is distinguished from *L. album* subsp. *barbatum* only few morphologic differences, which is a minor characteristic. Therefore, based on the researcher's judgment, it was excluded from this study. As a result, the interactive key developed for this study classifies the *Lamium* into four taxa.

Table 29. List of Korean *Lamium* and taxa included in this study

Scientific name	CVPK	NLSK	WFO	Original reference
Lamium album L.	왜광대수염	왜광대수염	accepted	Sp. Pl. 2: 579 (1753)
***Lamium album* L. subsp. *barbatum* (Siebold & Zucc.) Mennema**	광대수염		accepted	Leiden Bot. Ser. 11: 70 (1989)
Lamium album L. var. *barbatum* (Siebold & Zucc.) Franch. & Sav.		광대수염	Syn. *Lamium album* subsp. *barbatum*	Enum. Pl. Jap. 1: 383 (1875)
***Lamium amplexicaule* L.**	광대나물	광대나물	accepted	Sp. Pl. 2: 579 (1753)
***Lamium purpureum* L.**	자주광대나물	자주광대나물	accepted	Sp. Pl. 2: 579 (1753)
Lamium purpureum L. var. *hybridum* (Vill.) Vill.	유럽광대나물	유럽광대나물	accepted	Hist. Pl. Dauphiné 2: 385 (1787)
***Lamium takesimense* Nakai**	섬광대수염	섬광대수염	unchecked	Not available

3.1.29 *Leonurus*

Leonurus native to Korea is represented by two taxa, with no discrepancies found in any of the literature reviewed for this study.

Table 30. List of Korean *Leonurus* and taxa included in this study (bold)

Scientific name	CVPK	NLSK	WFO	Original reference
***Leonurus japonicus* Houtt.**	익모초	익모초	accepted	Nat. Hist. (Houttuyn) 9: 366 (1778)
***Leonurus macranthus* Maxim.**	송장풀	송장풀	accepted	Mém. Acad. Imp. Sci. St.-Pétersbourg, Divers Savans 9: 476 (1859)

3.1.30 *Paraphlmis*

Paraphlomis in Korea is represented by a single taxon, with no discrepancies found in any of the literature reviewed for this study. However, due to the absence of herbarium sheets at KH and SWU for verification, this study adopted a zero taxa classification.

Table 31. List of Korean *Paraphlomis* and a taxon included in this study (bold)

Scientific name	CVPK	NLSK	WFO	Original reference
***Paraphlomis koreana* S.C.Ko & G.Y.Chung**	속단아재비	속단아재비	accepted	Phytotaxa 175: 51 (2014)

3.1.31 *Phlomis*

P. maximowiczii was excluded from this study due to the fact that the available herbarium sheets were not collected from within Korea. Therefore, this study consolidates the classification into a single taxon.

Table 32. List of Korean *Phlomis* and a taxon included in this study (bold)

Scientific name	CVPK	NLSK	WFO	Original reference
Phlomis maximowiczii Regel	큰속단	큰속단	Syn. Phlomoides maximowiczii	Trudy Imp. S.-Peterburgsk. Bot. Sada 9: 594, t. 10, f. 18 (1884)
***Phlomis umbrosa* Turcz.**	속단	속단	Syn. Phlomoides umbrosa	Bull. Soc. Imp. Naturalistes Moscou 13: 76 (1840)

3.1.32 *Pogostemon*

In cases where the taxonomic recognition differs between the two institutions, the accepted name in the WFO is followed. Accordingly, this study adopts two taxa From *Pogostemon* rather than *Dysophylla*

Table 33. List of Korean *Pogostemon* and taxa included in this study (bold)

Scientific name	CVPK	NLSK	WFO	Original reference
Pogostemon stellatus **(Lour.) Kuntze**	물꼬리풀		accepted	Revis. Gen. Pl. 2: 429 (1891)
Pogostemon yatabeanus **(Makino) Press**	전주물꼬리풀		accepted	Bull. Brit. Mus. (Nat. Hist.), Bot. 10: 74 (1982)

3.1.33 *Stachys*

S. agrarian and *S. oblongifolia* recognized the same scientific names between the two institutions. However, S. agraria was reported as an unrecorded species (Jeong et al. 2016), but it was not considered a naturalized taxon. *S. oblongifolia* was also excluded as it is native to North Korea. Also, *S. sieboldii* is a cultivated species, and there are no specimens of *S. baicalensis* var. *angustifolia* at the KH or the SWU. Additionally, *S. riederi* var. *hispidula* and *S. baicalensis* var. *hispidula* were found to have very few specimens, with most of the *S. riederi* var.

hispidula specimens collected from Baekdu Mountain (North Korea). Therefore, this study adopts one taxon

Table 34. List of Korean *Stachys* and a taxon included in this study (bold)

Scientific name	CVPK	NLSK	WFO	Original reference
Stachys baicalensis Fisch. ex Benth.		털석잠풀	Syn. *Stachys riederi*	Labiat. Gen. Spec. 543 (1834).
Stachys baicalensis var. *angustifolia* Honda		가는잎털석잠풀	Syn. *Stachys riederi*	Bot. Mag. (Tokyo) 46: 374 (1932).
Stachys baicalensis var. *hispidula* (Regel) Nakai		개석잠풀	Syn. *Stachys riederi* var. *hispidula*	Bot. Mag. (Tokyo) 34: 46 (1920)
Stachys japonica Miq.		석잠풀	Syn. *Stachys riederi* var. *japonica*	Ann. Mus. Bot. Lugduno-Batavi 2: 111 (1865).
Stachys riederi Cham. var. *hispidula* (Regel) H.Hara	털석잠풀		accepted	Bot. Mag. (Tokyo) 41: 144 (1937)
Stachys riederi Cham. var. *hispidula* (Regel) H.Hara f. *angustifolia* (Honda) H.Hara	가는잎털석잠풀		unchecked	Fl. Jap. (Iwatsuki et al., eds.) 3a: 347 (1993)
***Stachys riederi* Cham. var. *japonica* (Miq.) H.Hara**	석잠풀		accepted	Bot. Mag. (Tokyo) 51: 144 (1937)
Stachys agraria Schltdl. & Cham.	애기석잠풀	애기석잠풀	accepted	Linnaea 5 : 100 (1830)
Stachys oblongifolia Benth.	우단석잠풀	우단석잠풀	accepted	Pl. Asiat. Rar. 1 : 64 (1830)

3.2 Character used in this study

All characters and character states were extracted based on the FL, resulting in 165 characters. Among them, 56 character states were selected for this study based on specific criteria (Table 35). The selected characters comprise 13 quantitative characters and 43 qualitative characters.

Table 35. List of characters and character states used in this study

Entire plant/distribution		
	Plant habit	
		Herb; Shrub; Tree
	Plant hight (cm)	
	Distribution	
		Gyeonggi; Gangwon; Chungbuk; Chungnam; Jeonbuk; Jeonnam; Gyeongbuk; Gyeongnam; Jeju; Ulleungdo; Geoje Island
Underground part		
		Rhizome; Stolon; Tuber; Root tuber
Stem		
	Stem branching	
		Branching; Not branching
	Stem cross−section	
		Four−angled; Rounded
	Stem surface	
		Glaborous; Sparsely hairy; Hairy
Radical leaf		
	Leaf shape	
		Lanceolate; Ovate/Broadly ovate/Triangular ovate; Oblanceolate; Round and palmetly lobed; Elliptic
Cauline leaf		
	Simple or compound leaf	
		Unlobed simple leaf; Deeply lobed simple leaf; Palmately compound leaf; Pinnately compound leaf
	Leaflets number	
	Terminal or middle leaflet shape (in the compound leaf)	
		Lanceolate/Ovate; Elliptic/Oblong; Rhombic
	Petiole length (cm)	

Table 35. (Continued)

	Petiole surface	
		Glabrous; Hairy (including sparsely hairy)
	Leaf arrangement	
		Opposite; Whorled
	Number of leaves at a node	
	Leaf length (cm)	
	Leaf width (cm)	
	Leaf blade shape	
		Linear; Ovate/Deltate/Lanceolate; Obovate/Oblanceolate; Oblong/Elliptic; Rhombic; Circular; Reniform
	Leaf texture	
		Coriaceous (leathery); Not coriaceous (including chartaceous and membranous)
	Leaf apex	
		Caudate−acuminate; Acuminate; Acute; Obtuse; Rounded
	Leaf base	
		Cuneate/Attenuate; Acute; Obtuse; Rounded; Truncate; Cordate
	Leaf margin/lobe	
		Entire; Serrate; Crenate; Double crenate; Ciliate; Dentate; Sinuate; Pinnately lobed
	Leaf adaxial surface	
		Glabrous; Hairy (including sparsely hairy)
	Lear abaxial surface	
		Glabrous; Hairy (including sparsely hairy)
Inflorescence		
	Inflorescence/flower position	
		Terminal; Axillary; Super−axillary
	Inflorescence length (cm)	
	Inflorescence width (cm)	
	Inflorescence type	
		(Cylindrical spike−like) Verticillaster; (Secund spike−like) Verticillaster; Thyrse; Raceme; Solitary in axils
	Angle of opposite flowers	
		Ca. 120 degrees; < 90 degrees
	Inflorescence/Peduncle/Pedicel surface	
		Glaborous; Hairy (including sparsely hairy)
	Bract shape	
		Linear; Ovate/Lanceolate/Deltate; Obovate/Oblanceolate; Oblong/Elliptic; Rhombic; Circular

Table 35. (Continued)

	Angle of opposite flowers	
		Ca. 120 degrees; < 90 degrees
	Inflorescence/Peduncle/Pedicel surface	
		Glaborous; Hairy (including sparsely hairy)
	Bract shape	
		Linear; Ovate/Lanceolate/Deltate; Obovate/Oblanceolate; Oblong/Elliptic; Rhombic; Circular
	Bract length (mm)	
	Bract width (mm)	
	Bracteole length (mm)	
	Bracteole margin	
		Ciliate; Not ciliate
Flower		
	Calyx shape	
		Sepals connated; Sepals not connated
	Calyx surface	
		Glabrous; Hairy (including sparsely hairy)
	Calyx lobe shape	
		Linear/Subulate; Lanceolate; Ovate; Deltate; Obovate
	Calyx lobe length	
		Same length; Different length (2−labiate)
	Calyx lobe apex	
		Needlelike; Acuminate/Aristate; Apiculate; Acute; Obtuse
	Scutellum in upper calyx	
		Presence; Absence
	Scutellum length (mm)	
	Floral symmetry	
		Bilaterally; Actinomorphic; Nearly actinomorphic
	Corolla shape	
		2−labiate tubular; 2−labiate campanulate; Funnel−form
	Corolla color	
		Pink; Purple; Blue; White; Pale yellow
	Corolla length (cm)	
	Outer corolla surface	
		Glabrous; Hairy (including sparsely hairy)
	Corolla tube base angle (degree)	
		0−20; 30−60; ca. 90
	Upper corolla lip	
		1−lobed; 2−lobed; 4−lobed; Obsolete

Table 35. (Continued)

Lower corolla lip	
	1-lobed; 3-lobed; 5-lobed
Lower corolla lip spots	
	Purple spots; Pink spots; Blue spots
Stamen number	
	Two; Four
Stamen length comparison	
	Didynamous; Same length
Stamen protrusion to corolla	
	Protrude; Not protrude
Anther length (mm)	
Fruit appendage	
	Winged margins; Not winged margins; Tuberculate corky crest; Not tuberculate corky crest

3.3 Interactive key program

The completed interactive key for Korean *Lamiaceae* species, developed through this study, is available on the web: http://amborella.net/LamiaceaeProject/02-KoreanLamiaceae/korean_lamiaceae_interactive_key_player.html. This interactive key was implemented using the software Lucid Builder v4.0 and is accessible across multiple devices, including mobile phones, tablets, and computers. The interactive key is designed with four main panels. To make it easier for non-experts to understand terms that may be confusing, a series of illustrations of character and character states in the Lamiaceae are included (appendix 1). Additionally, detailed information on the selected vouchers is provided in appendix 2.

The left side displays characters and character states, while the right side displays taxa (Fig 1,2).

- Top−left box: Displays selectable characters and character states.
- Bottom−left box: Displays characters that have already been selected.
- Top−right box: Displays the remaining taxa.
- Bottom−right box: Lists taxa that have been excluded based on the selected characters.

By clicking on the image of an excluded taxon, users can view the reason for its exclusion.

The top−left section of the interactive key includes 14 buttons.

- Leftmost button: Resets all selected characters.
- Up and down arrows button: Expands or collapses selected character states.
- Search button (magnifying glass): Allows users to search for specific characters.
- Image icon: Displays illustrations of the characters and character states on the current screen.

- Magic wand button: Suggests the most informative characters as determined by the program.
- Scissors button: Removes unnecessary character states.
- List icon: Displays how each character is entered for all taxa.
- Lightning icon: Indicates key characters for rapid identification.
- Question mark button: Explains the reason for the exclusion of particular taxa (Fig 3)

Fig. 1. The main page of the program. It is divided into four windows: Features Available, Features Chosen, Entities Remaining, and Entities Discarded.

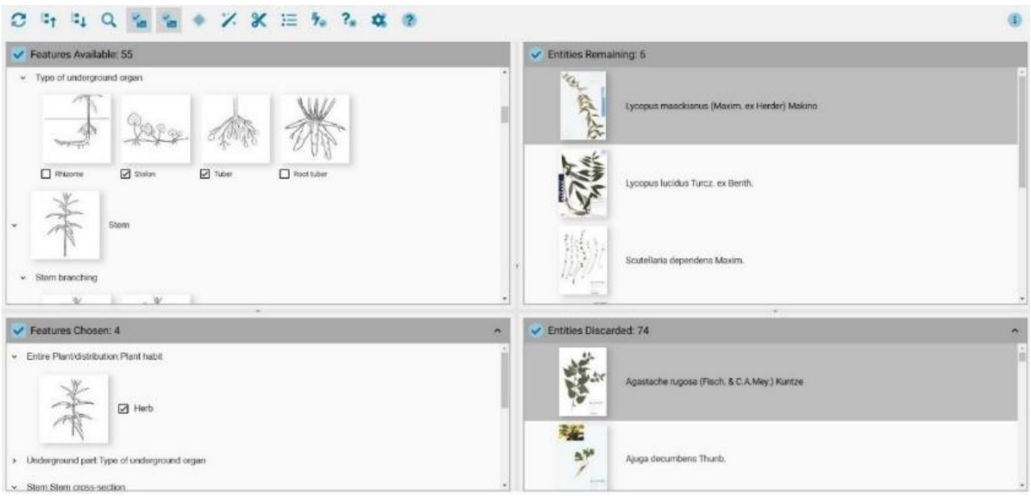


Fig. 2. Input window when selecting the quantitative trait 'Plant height'. Users may input either a single value or a range.

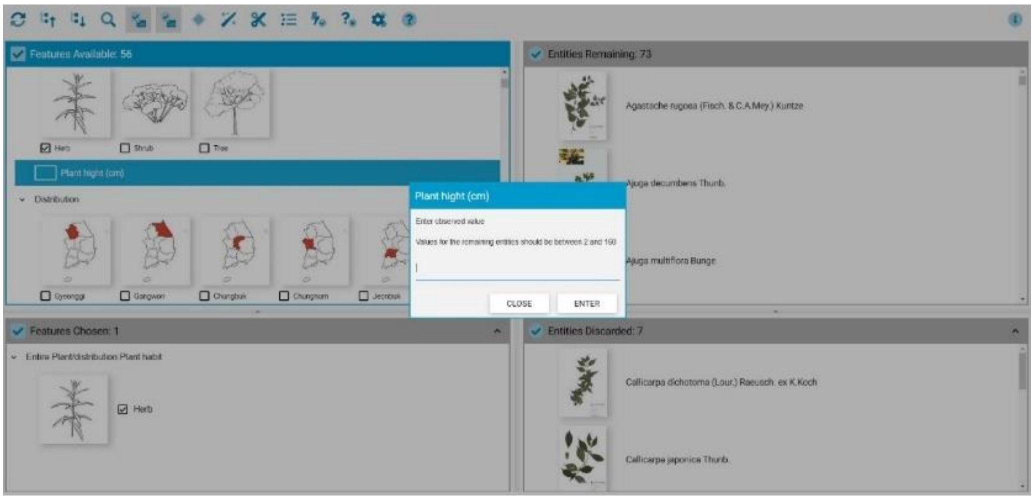
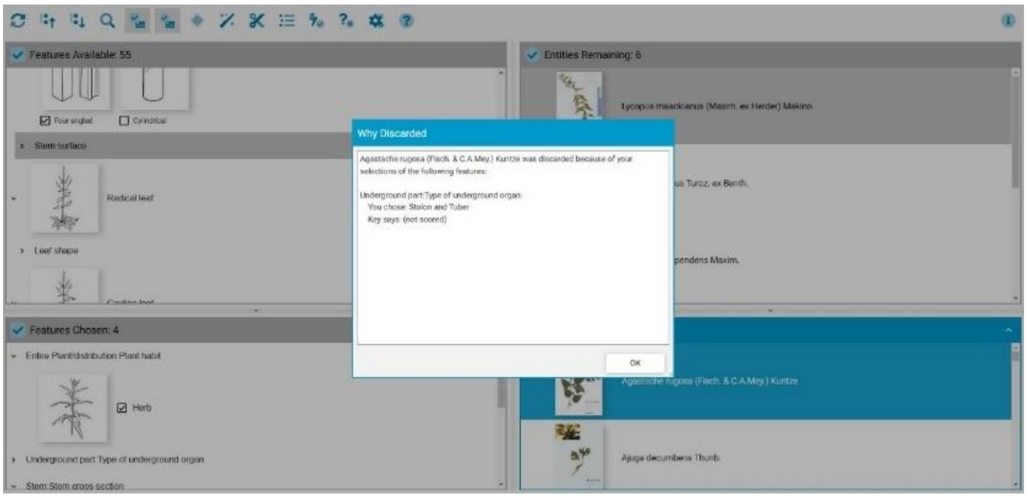


Fig. 3. A window showing why specific taxa were excluded at the current step.



Chapter 4. Discussion

4.1 Discussion on taxon selection

In the process of organizing taxa for constructing the interactive key for Korean Lamiaceae, several issues were identified. These included cases where it was unclear whether taxa were indeed native, taxa with ambiguous classifications requiring further research, taxa recognized differently by various researchers, and taxa with insufficient evidence to establish clear distinctions. Given the scope of this study, only those taxa with available vouchers close to the described type were selected. However, the taxa listed below were identified as requiring additional research. Furthermore, many of these taxa had fewer than 10 identifiable character states in the interactive key (Table 40).

1) *Callicarpa*

: *C. japonica* var. *taquetii, C. mollis* var. *microphylla,*
Callicarpa × *shirasawana*

The following taxa within the *Callicarpa* require further research:

C. japonica var. *taquetii* needs additional studies at the molecular level, and *C. mollis* var. *microphylla* also requires further investigation to assess its taxonomic status, given reports that its characteristics vary depending on habitat. Additionally, *Callicarpa* × *shirasawana* requires a review of its taxonomic status, as individuals found are considered natural hybrids, pending further research (Lee 2021).

2) *Clinopodium*

No comprehensive studies have been conducted on the classification of the *Clinopodium* native to Korea, and even the taxa included in the FL often exhibit discrepancies or ambiguities between character descriptions and actual specimens. Morphological and molecular studies are needed to clarify the classification of this genus.

3) *Glechoma*

Both *G. grandis* and *G. longituba* are used domestically, with researchers divided on which taxon to recognize. *G. grandis* is naturally distributed in Japan (Yamazaki 1993), while both taxa are naturally distributed in China (Hedge and Li 2004). Therefore, comparative studies of floras and specimens from these two countries could aid in unifying the classification of these taxa.

4) *Mosla*

Since the 2011 dissertation (Park 2011), no further research has been conducted on this genus. The taxa included in the FL also show discrepancies or ambiguities between character descriptions and actual specimens. Among the seven recognized taxa, *M. japonica* f. *thymolifera* and *M. dianthera* var. *nana* were not available as specimens in the KH and SWU collections, and online access was also limited. Additionally, *M. japonica* f. *thymolifera* appears to be relatively well-defined but is represented by very few specimens, and *M. dianthera* var. *nana* is a variety of *M. dianthera*, with unclear distinction. Therefore, further morphological and molecular research on this genus is recommended.

5) *Thymus*

Thymus is recognized by both institutions as having two taxa, with *T. quinquecostatus* var. *japonicus*, reported to grow only on Ulleungdo Island, differentiated from *Thymus quinquecostatus* by some morphological differences. Domestically, *T. quinquecostatus* var. *japonicus* is also widely used as an ornamental plant. However, the FL (Park 2018b) recognizes only *Thymus quinquecostatus* as a taxon, and the National Standard List of Plant Species also notes that further research is needed to clarify its taxonomic relationship with *T. quinquecostatus* (Korea National Arboretum and The Plant Taxonomic Society of Korea 2003; National Institute of Biological Resources 2018).

6) *Prunella*

P. vulgaris is distinguished by the presence of stolons, branching at the base of the main stem, and the type and density of stem hairs (Hedge and Li 2004; Kim and Park 2018b; Lee 1989). However, specimens of *P. vulgaris* preserved overseas also exhibit sparsely or densely distributed crisped hairs, similar to those of *Prunella vulgaris* subsp. *asiatica*. Therefore, using the presence of stolons and basal branching as distinguishing criteria for *P. vulgaris* was deemed unreliable. It is necessary to study the relationship between the 2 taxa by examining both domestic and overseas specimens to determine if there are clear morphological characters that separate the two or if they are molecularly the same taxon.

7) *Clerodendrum*

Clerodendrum trichotomum has two varieties, *C. trichotomum* var. *ferrugineum* and *C. trichotomum* var. *esculentum*, with definitions that remain unclear. Only one specimen of *C. trichotomum* var. *esculentum* exists in the KH, and previous studies have reported that this variety is native to the southern regions of Japan (Mizusawa et al. 2019). It is necessary to verify whether the domestic *C. trichotomum* var. *esculentum* corresponds to the Japanese taxon. Similarly, *C. trichotomum* var. *ferrugineum* lacks a specimen image in the KH database in Korea. This variety is reported to be distributed in China, Japan, and Taiwan (National Arboretum 2007), but it is essential to confirm whether the few domestic specimens and plants correspond to the same taxon. The Flora of China recognizes this taxon based on the characteristic of densely rust colored hairs (Chen and Gilbert 2004). Therefore, additional comparative research with neighboring countries is needed to determine whether this taxon exists domestically.

8) *Teucrium viscidum*

According to the FL (Kim and Park 2018a), *T. viscidum* and *T. viscidum* var. *miquelianum* differ in over 10 character states. However, many collected specimens did not align with the described features. It is necessary to clarify the differences between these two taxa by comparing specimens of *T. viscidum* from Japan, where it is reported to be native, with those of *T. viscidum* var. *miquelianum* from China, where it is primarily found.

9) *Lamium*

The FL (Park 2018c) differentiates this taxon from *L. album* subsp. *barbatum* by 7 characters, including hair density and leaf length and width. Although specimens are absent from the KH, they are available in significant numbers at the National Institute of Biological Resources. Verification is needed to determine whether these specimens align with the interactive key, and further comparisons with *L. album* from China would clarify its classification. The Flora of China also notes that this taxon requires additional research (Hedge and Li 2004). Similarly, further research is needed on the taxonomic position of *Lamium takeshimense*.

10) *Phlomis maximowiczii*

According to the FL (Park 2018c), this taxon is native to Gangwondo and central parts of the Korean Peninsula, but no specimens have been verified domestically. Further research is needed to confirm its native habitat and obtain representative specimens.

11) *Stachys*

S. baicalensis, *S. baicalensis* var. *angustifolia*, *S. baicalensis* var. *hispidula*, *S. riederi* var. *hispidula*

These taxa are considered native, but very few specimens are available, some of which were collected in North Korea. Additional research is necessary to confirm whether these taxa genuinely exist in South Korea.

4.2 Discussion on character selection

Two primary issues were identified when constructing an interactive key based on the FL. First, while some characters and character states were clearly stated in the flora, they were often ambiguous to determine in the field. Second, the criteria for character states were inconsistent across genera or families in the literature. These issues suggest the need to refine the morphological characters used for identification. The characters requiring careful consideration for the interactive key are as follows:

Ambiguous character: presence of hairs

Since we primarily selected characters that could be observed with the naked eye, subtle hairs might not be discernible when using touch or a loupe to examine the plant. Therefore, in addition to the precise state of "hairs present" the state "hairs absent" was added. For taxa, where visual observation was unclear, we also included an option of "possible error" (Bittrich et al. 2012).

Ambiguous character: leaf apex, base, and margin

Qualitative leaf characters such as apex, base, and margin are important vegetative characters. Despite their clear descriptions in flora and literature, they were often ambiguous in the field. For instance, the definitions of acuminate, aristate, acute, and obtuse serrate leaf apices are precise, but in-field observation can still be challenging. To address this, the researcher added similar character states based on specimen observations. For leaf bases, which were difficult to determine from specimens, the option "possible error" was also included.

Ambiguous character: quantitative characters

Many quantitative characters were used, including plant height, petiole length, leaf length, width, and inflorescence length and width. Even when a 10% range was allowed for single-value characters, there were numerous cases where character states fell outside these values. Minimum and maximum values based on observable samples have been added to reduce these errors. It was concluded that the ranking mode of the interactive key was more suitable than the filter mode.

Ambiguous character: presence or absence of branching

Branching presence is a relatively clear character for distinguishing species. However, depending on the plant's environment and growth conditions, literature may indicate branching even though many individuals do not exhibit it. Hence, for plants marked as "branched," the state "not branched" was included, while "not branched" remained unchanged. This information was cross-checked with specimens.

Inconsistent character: inflorescence type

The inflorescence type was described inconsistently for specific taxa of the Lamiaceae family, which previously belonged to Verbenaceae. Except for *Scutellaria*, all taxa in Lamiaceae have a whorled cyme. However, terms such as racemose-like, unilateral racemose, capitulate, and dense spike were used. Many taxa were difficult to classify as cymes based on condensed peduncles and pedicels that appeared axillary. In the *Callicarpa*, formerly in Verbenaceae, the description "cymose" was also used, even though it fell under the broader category of determinate inflorescences. Thus, based on the researcher's judgment, the inflorescence types were reclassified into five categories: 1) whorled cymose (racemose, axillary), 2) unilateral whorled cymose, 3) racemose, 4) dense spike, and 5) solitary in axils. Illustrations of representative character states were included to prevent misidentification in the field.

Inconsistent character: corolla type

The corolla of Lamiaceae is described in various forms, such as bilabiate, campanulate, tubular, tubulose–campanulate, cupulate, and funnel–shaped. However, upon closer inspection, it could be distinguished between bilabiate with asymmetric corolla length and funnel–shaped with equal lobe length. Tubular and campanulate forms were differentiated based on whether the corolla length exceeded its width (tubular) or not (campanulate). Based on the researcher's judgment, corolla types were classified into bilabiate, campanulate–tubular, and funnel–shaped.

Inconsistent character: number of corolla lobes

The number of lobes in the upper and lower lips of Lamiaceae corollas was inconsistently described for different taxa. According to the flora, *Ajuga* has three lobes on the lower lip, *Scutellaria* has two, and *Stachys* has slightly two-lobed. However, the classification of upper and lower lips can vary. For *Scutellaria* and *Stachys*, the central lobe of the corolla was found to be bifid, while the lateral lobes were not as visible. Based on this, the researcher reorganized the character states.

4.3 Discussion on the interactive key

When a character cannot be observed for dichotomous keys or its importance in species identification is unknown, it can be challenging for non-experts to know where to begin identification. To address this issue, the interactive key listed only taxonomically relevant characters, simplifying identification. While data were extracted based on the FL (2018), not all taxa had identical character data. Additional information was therefore extracted from related literature and dry specimen data. Notably, the presence of hairs was confirmed through specimens.

Even if the result from the interactive key yields one taxon, the outcome may still be questioned. While traditional keys do not allow additional character selection for further differentiation, the interactive key offers filtering and ranking options, which users can choose at the beginning or during identification. Immediate filtering eliminates mismatched characters, whereas ranking shows the likelihood of each taxon in percentage terms, allowing identification even if some characters are misinterpreted. Users can include additional characters for further identification even when reaching a 100% match, considering taxa with high matching percentages.

The efficiency of this interactive key can be evaluated using "score analyzer", a tool in the Lucid program. This tool graphically shows how well character states distinguish pairs of taxa and how many characters help to differentiate specific taxa. The analysis indicated that most taxa could be distinguished by an average of 40 character states (Fig 4.), with some distinguished by up to 70. Even when only vegetative characters were analyzed, genera could be separated by an average of 20 character states (Fig 5.). The smallest number of characters required for distinguishing a taxon was three, and the following taxa could be identified with fewer than ten characters (Table 36). Though more characters could be added for better results, the conclusion was that these taxa have relatively fewer morphological differences on average.

Fig. 4. Graph showing the number of characters required to distinguish pairs of taxa. The x−axis and y−axis represent the number of characters separating two taxa and the number of taxa pairs distinguished, respectively.

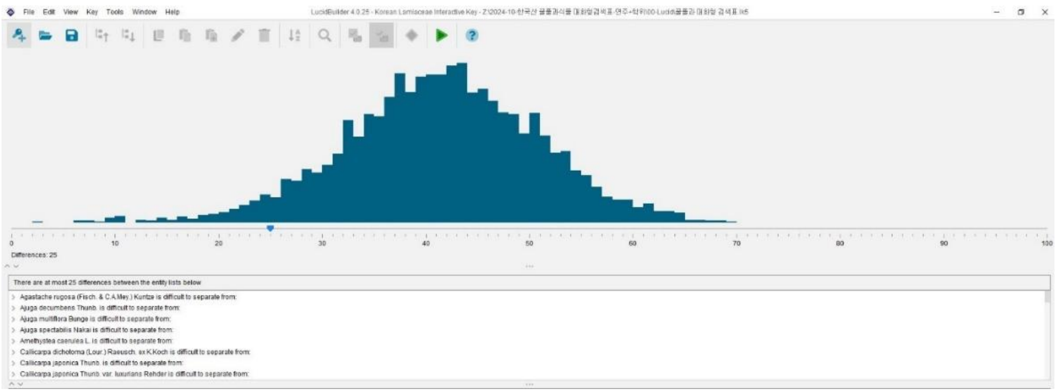


Fig. 5. Graph showing the number of vegetative characters required to identify pairs of taxa.

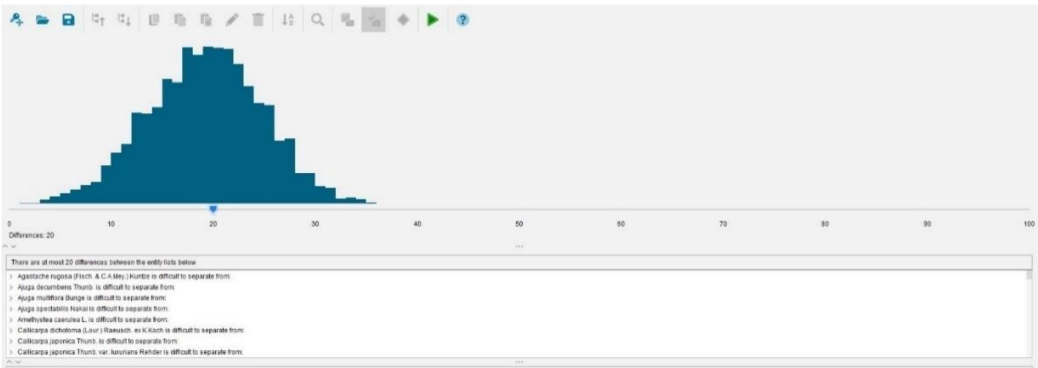


Table 36. Pairs of taxa in the Korean Lamiaceae interactive key distinguishable by 10 or fewer characters.

Number of Characters	taxa
3	*Isodon inflexus* var. *canescens* and *Isodon inflexus*
6	*Callicarpa japonica* var. *luxurians* and *Callicarpa japonica*
7	*Clinopodium micranthum* and *Clinopodium multicaule*
8	*Clinopodium chinense* var. *parviflorum* and *Clinopodium multicaule* var. s*hibetchense* *Scutellaria indica* and *Scutellaria indica* var. *coccinea*
9	*Scutellaria indica* var. *coccinea* and *Scutellaria pekinensis* var. *transitra* *Scutellaria pekinensis* var. *alpina* and *Scutellaria pekinensis* var. *ussuriensis* *Lycopus lucidus* and *Lycopus maackianus*
10	*Isodon japonicus* and *Isodon inflexus* *Teucrium viscidum* and *Teucrium viscidum* var. *miquelianum*

Chapter 5. Conclusion

This study not only developed an interactive key but also integrated the morphological characters of Korean Lamiaceae taxa, providing essential data for future plant taxonomy research and proposing taxa that require further investigation. This research developed an interactive key comprising 82 taxa and 56 characters for the Lamiaceae, known for its extensive research and high utility.

Further testing of this key's effectiveness is needed with both experts and non−experts. Currently, the interactive key is limited to Lamiaceae plants found in Korea, but it can be expanded to neighboring countries, such as Japan and China, in the future. Such expansion would facilitate the identification of various Lamiaceae species and provide a foundation for resolving classification inconsistencies across regions and contribute to studies on biogeography and related taxonomic research.

LITERATURE CITED

Bendiksby M, Thorbek L, Scheen AC, Lindqvist C, Ryding O (2011) An updated phylogeny and classification of Lamiaceae subfamily Lamioideae. Taxon 60: 471-484.

Bentham G, Hooker JD (1876) Verbenaceae and Labiatae. Genera Plantarum. Lovell Reeve & Co., Williams & Norgate, London, 1131-1123.

Bittrich V, Souza CSD, Coelho RLG, Martins MV, Hopkins MJG, Amaral MCE (2012) An interactive key (Lucid) for the identifying of the genera of seed plants from the Ducke Reserve, Manaus, AM, Brazil. Rodriguésia 63: 055-064.

Brach AR, Song H (2005) ActKey: A Web-Based Interactive Identification Key Program. Taxon 54.

Briquet J (1895-1897) Labiatae. In: Engler AP, K. (Ed) Die Natürlichen Pflanzenfamilien. Engler and Prantl, Leipzig, Germany.

Catalogue of Life. https://www.catalogueoflife.org/ [accessed June 10.2024]

Flora of China. http://www.efloras.org/browse.aspx?flora_id=2&start_taxon_id=10941

Choi C, Han K, Lee J, So S, Hwang Y, Kim M (2012) A New species of Elsholtzia (Lamiaceae): E. byeonsanensis M. Kim. Korean Journal of Plant Taxonomy 42: 197-201.

Chung Y-H, Kim H (1989) Callicarpa chejuensis, a new species from Korea. Korean Journal of Plant Taxonomy 19: 21-30.

Dallwitz MJ (1993) An Introduction to Computer Images. DELTA Newsletter 8: 7–9.

DELTA Newsletter Archive. https://www.delta-intkey.com/www/dn.htm 2024]

Doorenweerd C, van Haren M, Schermer M, Pieterse S, van Nieukerken EJ (2014) A Linnaeus NGTM interactive key to the Lithocolletinae of North-West Europe aimed at accelerating the accumulation of reliable biodiversity data (Lepidoptera, Gracillariidae). ZooKeys 422: 87-101.

Dunn CP (2003) Keeping taxonomy based in morphology. Trends in Ecology & Evolution 18: 270-271.

Flannery MC (2001) Biology Today: Where Is Biology? The American Biology Teacher 63: 442-447, 446.

Flora of Korea (2018) Verbenaceae, Lamiaceae. In: Committee FoKE (Ed) Flora of Korea : Asteridae: Loganiacae to Oleaceae. National institute of Biological Resources, Incheon, Republic of Korea, 71-127.

Goodall DW (1968) Identification by computer. BioScience 18: 485-488.

Grenié M, Berti E, Carvajal-Quintero J, Dädlow GML, Sagouis A, Winter M (2022) Harmonizing taxon names in biodiversity data: A review of tools, databases and best practices. Methods in Ecology and Evolution 14: 12-25.

Griffing LR (2011) Who invented the dichotomous key? Richard Waller's watercolors of the herbs of Britain. American Journal of Botany 98: 1911-1923.

Harley RM, Atkins, S., Budantsev, A. L., Cantino, P. D., Conn, B. J., Grayer, R. (2004) Labiatae. Springer, Berlin, Heidelberg.

Flora of China. http://www.efloras.org/flora_page.aspx?flora_id=2

Henderson NC (1962) A taxonomic revision of the genus Lycopus (Labiatae). American Midland Naturalist 68: 95–138.

Hong J-K, Kim J-H, Kim Y-R, Kim J-S (2021) Two Unrecorded Alien Plants of Korean Peninsula: Pilea microphylla (L.) Liebm. (Urticaceae) and Elsholtzia griffithii Hook. f. (Lamiaceae). The Plant Resources Society of Korea.

Hwang KA (2005) Morphological and Molecular Phylogenetics of Korean Elsholtzia (Elsholtzia Willd.) Species. Seoul Korea: Ewha Womans University.

Im H-T (2018) Verbenaceae. In: Committee FoKE (Ed) Flora of Korea. Incheon, Republic of Korea.

Institute of Scientific Research of Manchoukuo (1937) Report of the Institute of Scientific Research of Manchoukuo. Hsinching, Manchoukuo, 265 pp.

Jang H-D, Jeong K-K, Nam M-J, Song J-H, Moon H-K, Choi HJ (2022) Mosladadoensis (Lamiaceae), a new species from the southern islands of South Korea. PhytoKeys 208: 185-199.

Jang T-S, Lee J, Hong S-P (2014) A systematic study of Glechoma L. (Lamiaceae) based on micromorphological characters and nuclear ribosomal ITS sequences. Korean Journal of Plant Taxonomy 44: 22-32.

Jeon Y-C, Hong S-P (2006) A Systematic Study of Elsholtzia Willd. (Lamiaceae) in Korea. Korean Journal of Plant Taxonomy 36: 309-333.

Jeong KS, Jang C-S, Park SH, Lee JS, Yoon SM, Kim TH, Shin CH, Choi K (2016) Two unrecorded naturalized plants in Korea: Stachys agraria and Dracocephalum moldavica (Lamiaceae). Korean Journal of Plant Taxonomy 46: 413-419.

Ji S-J, Yang J-C, Jung S-Y, Chang C, Park S-H, Kang Y-S, Oh S-H, Lee Y-M (2012) Two newly naturalized plants in Korea: Nuttallanthus canadensis (L.) D. A. Sutton and Lamium purpureum var. hybridum (Vill.) Vill. Korean Journal of Plant Taxonomy 42: 91-97.

Jin X-J, Huang Y, Wei Y-K, Ma Q, Liu L-X, Fu Z-X, Wu G-F, Zhang Y-H, Li P (2022) Elsholtzia zhongyangii (Lamiaceae), a new species from Sichuan, China. PhytoKeys 193: 77-88.

Judd WSC, C. S.; Kellogg, E. A.; Stevens, P. F.; Donoghue, M. J. (2016) Plant Systematics: A Phylogenetic Approach. Sinauer Associates.

Kattge J, DÍAz S, Lavorel S, Prentice IC, Leadley P, BÖNisch G, Garnier E, Westoby M, Reich PB, Wright IJ, Cornelissen JHC, Violle C, Harrison SP, Van Bodegom PM, Reichstein M, Enquist BJ, Soudzilovskaia NA, Ackerly DD, Anand M, Atkin O, Bahn M, Baker TR, Baldocchi D, Bekker R, Blanco CC, Blonder B, Bond WJ, Bradstock R, Bunker DE, Casanoves F, Cavender-Bares J, Chambers JQ, Chapin Iii FS, Chave J, Coomes D, Cornwell WK, Craine JM, Dobrin BH, Duarte L, Durka W, Elser J, Esser G, Estiarte M, Fagan WF, Fang J, FernÁNdez-MÉNdez F, Fidelis A, Finegan B, Flores O, Ford H, Frank D, Freschet GT, Fyllas NM, Gallagher RV, Green WA, Gutierrez AG, Hickler T, Higgins SI, Hodgson JG, Jalili A, Jansen S, Joly CA, Kerkhoff AJ, Kirkup D, Kitajima K, Kleyer M, Klotz S, Knops JMH, Kramer K, KÜHn I, Kurokawa H, Laughlin D, Lee TD, Leishman M, Lens F, Lenz T, Lewis SL, Lloyd J, LlusiÀ J, Louault F, Ma S, Mahecha MD, Manning P, Massad T, Medlyn BE, Messier J, Moles AT, MÜLler SC, Nadrowski K, Naeem S, Niinemets Ü, NÖLlert S, NÜSke A, Ogaya R, Oleksyn J, Onipchenko VG, Onoda Y, OrdoÑEz J, Overbeck G, Ozinga WA, PatiÑO S, Paula S, Pausas JG, PeÑUelas J, Phillips OL, Pillar V, Poorter H, Poorter L, Poschlod P, Prinzing A, Proulx R, Rammig A, Reinsch S, Reu B, Sack L, Salgado-Negret B, Sardans J, Shiodera S, Shipley B, Siefert A, Sosinski E, Soussana JF, Swaine E, Swenson N, Thompson K, Thornton P, Waldram M, Weiher E, White M, White S, Wright SJ, Yguel B, Zaehle S, Zanne AE, Wirth C (2011) TRY – a global database of plant traits. Global Change Biology 17: 2905-2935.

Kim H (2014) Taxonomic studies on the genus Ajuga (Lamiaceae). Kangwon National University.

Kim H, Song M-J (1999) A taxonomic study of the genus Callicarpa in Korea based on RAPD analysis. Korean Journal of Plant Taxonomy 29: 111-121.

Kim K-H, Park C-W (2018a) Teucrium. In: Committee FoKE (Ed) Flora of Korea. Incheon, Republic of Korea.

Kim M, Jung Y-H, Kim K-H, Kwon H-M, Song KJ, Kim S-C (2003) Genetic Variation of Thymus (Labiatae) in Korea Based on Chloroplast DNA Sequences. HORTICULTURE ENVIRONMENT and BIOTECHNOLOGY 44: 530-534.

Kim S-Y, Moon S-H, Kim J-S, Kim J-H, Lee BY (2013) First record of Ajuga nipponensis Makino (Lamiaceae) from Korea. Korean Journal of Plant Taxonomy 43: 165-167.

Kim S (2018) Isodon. In: Committee FoKE (Ed) Flora of Korea. Incheon, Republic of Korea.

Kim S, Park C-W (2018b) Prunella. In: Committee FoKE (Ed) Flora of Korea. Incheon, Republic of Korea.

Koch W, Elven H, Finstad AG (2022) Clavis: An open and versatile identification key format. PLoS One 17: e0277752.

Korean Plant Name Index. http://www.nature.go.kr/kpni/SubIndex.do [accessed September 2.2024]

Lee CS, Hwang KA, Kim JO, Seo MH, Lee NS (2011) Taxonomic_status_of_three_taxa_of_Elsholtzia_E_hal. Korean Journal of Plant Taxonomy.

Lee JW (2021) Phytogeographical study on genus Callicarpa L. from East Asia. Semyung University.

Lee TB (1989) Illustrated Flora of Korea. Hyang-mun publishing Co., Seoul.

Lee TB (2003) Coloured Flora of Korea. Hyangmunsa, Seoul Korea.

Lee Y-N (2000) The Genus Elsholtzia in Korea. Bulletin of Korean Plant Research 1: 48–54.

Léveillé H (1910) Decades plantarum novarum XL-XLII. Repertorium Specierum Novarum Regni Vegetabilis 8: 421–426.

Li B, Cantino PD, Olmstead RG, Bramley GLC, Xiang C-L, Ma Z-H, Tan Y-H, Zhang D-X (2016) A large-scale chloroplast phylogeny of the Lamiaceae sheds new light on its subfamilial classification. nature.

Li BO, R. G. (2017) Two new subfamilies in Lamiaceae. Phytotaxa 313: 222-226.

Li X, Hedge IC (1994) Elsholtzia. Science Press, Beijing

Missouri Botanical Garden Press, St. Louis, USA, 246-255 pp.

Linnæus C (1753) Prunella. Species Plantarum. Laurentii Salvii, Stockholm, Sweden, 600.

Ma Y, Kim S (2014) Morphological diagnostic characters of Isodon (Lamiaceae) in Korea. Korean Journal of Plant Taxonomy 44: 261-275.

Martellos S, Nimis PL (2015) From Local Checklists to Online Identification Portals: A Case Study on Vascular Plants. PLoS One 10: e0120970.

Mizusawa L, Ishikawa N, Yano O, Fujii S, Isagi Y (2019) Geographic Distribution of Ploidy Levels and Chloroplast Haplotypes in Japanese Clerodendrum trichotomum s. lat. (Lamiaceae). Acta Phytotaxonomica et Geobotanica 70: 87-102.

Moon H-K, Kim Y-C, Hong S-P (2013) Diagnostic characters and new populations of lycopus lucidus var. hirtus(Lamiaceae). Korean Journal of Plant Taxonomy 43: 99-102.

Morse LE (1971) Specimen identification and key construction with time-sharing computers. Taxon 20: 269-282.

Murguía-Romero M, Serrano-Estrada B, Ortiz E, Villaseñor JL (2021) Taxonomic identification keys on the web: tools for better knowledge of biodiversity. Revista Mexicana de Biodiversidad 92.

Nakai T (1915) Plantae novae Japonicae et Koreanae IV. Botanical Magazine (Tokyo) 29: 1.

Nakai T (1922) Verbenaceae. Experiment Station Govern. Chosen, Keijyo, 32-39 pp.

Korean Plant Names Index Committee. http://www.nature.go.kr/kpni/index.do

National List of Species of Korea (한반도의 생물다양성). https://species.nibr.go.kr/index.do [accessed Septmember 2.2024]

Norton GA, Patterson DJ, Schneider M (2000) LucID: A Multimedia Educational Tool for Identification and Diagnostics. international jounal of innovation in Science and Mathematics Education.

Oliver EGH, Forshaw N, Oliver IM, Volk F, Schumann AWS, Dorr LJ, Hoekstra RD, Musker SD, Nurk NM, Pirie MD, Rebelo AG (2024) Genus Erica: An identification aid version 4.00. PhytoKeys 241: 143-154.

Pankhurst R, Aitchison R (1975) An on-line identification program. Systematics Association, California, USA, 181-185 pp.

Park C-W (2007) Glechoma. In: Committee FoKE (Ed) The Genera of Vascular Plants of Korea. Academy Publishing Co., Seoul Korea, 824-825.

Park C-W (2018a) Glechoma. In: Committee FoKE (Ed) Flora of Korea. Incheon, Republic of Korea.

Park C-W (2018b) Thymus. In: Committee FoKE (Ed) Flora of Korea. Incheon, Republic of Korea.

Park K (2011) Phylogeny of Genus Mosla in Korea. Gyeongsan, Korea: Yeungnam University.

Park S (2018c) Phlomis. In: Committee FoKE (Ed) Flora of Korea. Incheon, Republic of Korea.

Siebold, Zuccarini (1846) Cercidiphyllum japonicum. Mathematisch-Physikalische Klasse der Königlichen Bayerischen Akademie der Wissenschaften 4: 238.

Son DC, Kim Y-Y, Ji S-J, Chang KS (2016a) Lectotypification of the name Lycopus coreanus (Lamiaceae). Phytotaxa 280.

Son DC, Lee D-h, Ji S-J, Chang KS, Yang J-C (2016b) A taxonomic review of Lycopus L. (Lamiaceae) in Korea.

Tsukaya H, Fukuda T, Yokoyama J (2003) Hybridization and introgression between Callicarpa japonica and C. mollis (Verbenaceae) in central Japan, as inferred from nuclear and chloroplast DNA sequences. Molecular Ecology 12: 3003-3011.

Wagstaff SJ, Hickerson L, Spangler R, Reeves PA, Olmstead RG (1998) Phylogeny in Labiatae sl, inferred from cpDNA sequences. Plant Systematics and Evolution 209: 265-274.

Wagstaff SJ, Olmstead RG (1997) Phylogeny of Labiatae and Verbenaceae inferred from rbcL sequences. Systematic Botany 22: 165-179.

World Flora Online. https://wfoplantlist.org/background [accessed 2 September.2024]

Yamazaki GMT (1993) Glechoma. In: Iwatsuki K, Yamazaki T, Boufford DE, Ohba H (Eds) Flora of Japan. Japan, 290.

Zuquim G, Tuomisto H, Prado J (2017) A free-access online key to identify Amazonian ferns. PhytoKeys: 1-15.

ABSTRACT IN KOREAN

국 문 초 록

손 연 주

생물학과

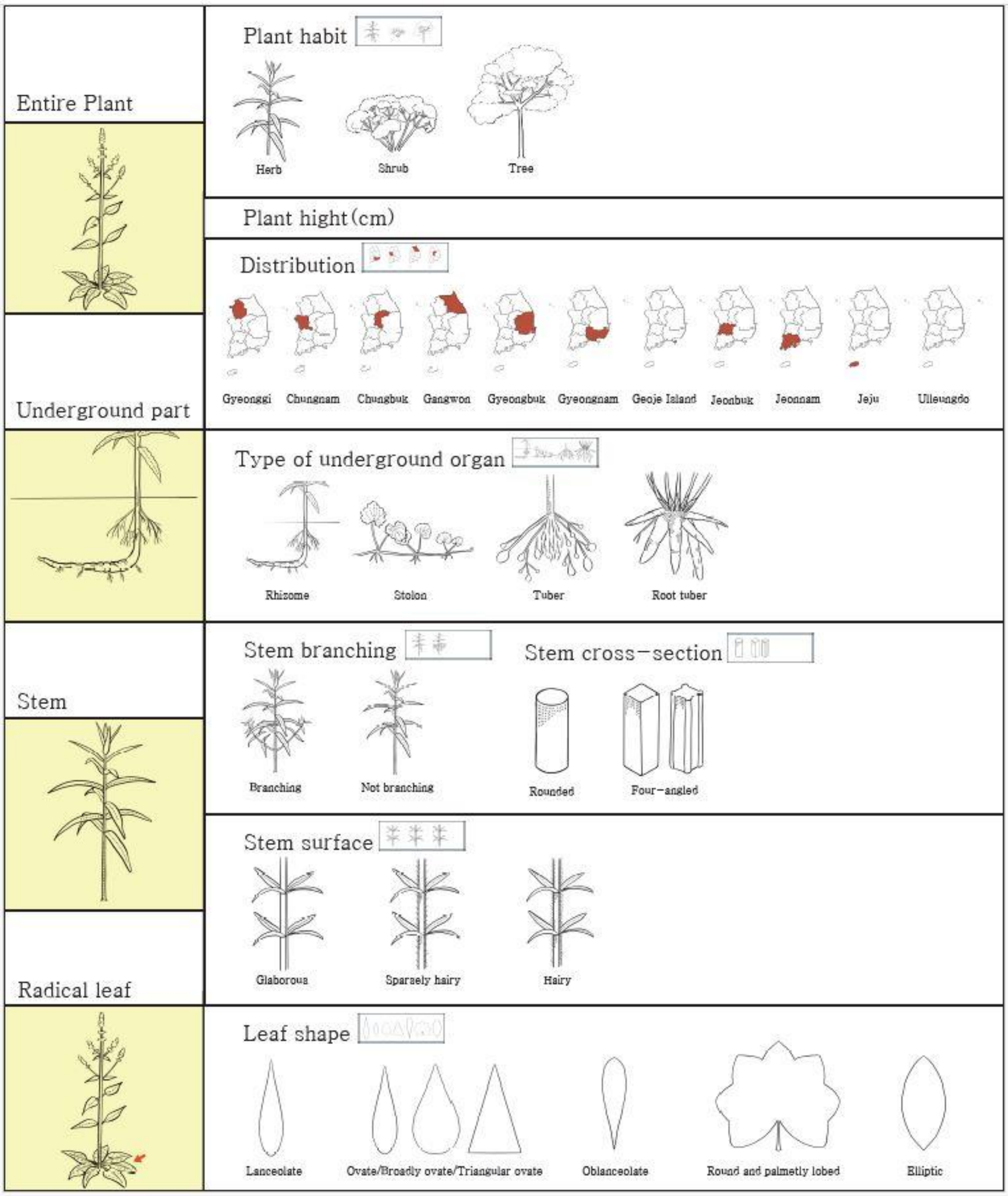
성신여자대학교 대학원

기술의 발전으로 종 동정에 다양한 기법이 활용되고 있지만, 형태에 기초한 분류는 여전히 여러 연구 현장에서 필수적이다. 꿀풀과는 속씨식물 중 여섯 번째로 큰 과로, 대부분이 약용, 조경용 등으로 다양하게 활용되며 국내에서도 대중들에게 친숙한 분류군이다. 본 연구에서는 지금까지 연구된 한국산 꿀풀과 166 개 분류군과 165 개 형태 형질을 정리하여 82 개 분류군을 선정하고 56 개 형질로 요약하였다. 이를 기반으로 Lucid Central 4.0 을 이용한 대화형 검색표를 구축하여 전문가를 포함한 일반인도 현장에서 관찰한 형질을 바탕으로 국내 꿀풀과 식물을 신속하고 정확하게 동정할 수 있도록 하였다(접속 url: http://amborella.net/LamiaceaeProject/02-KoreanLamiaceae/korean_lamiaceae_interactive_key_player.html).

본 연구에서 구축한 대화형 검색표는 한국 자생 꿀풀과 식물에 국한되지만, 향후 일본과 중국 등 인접 국가로 확장하여 다양한 꿀풀과 분류군의 동정을 원활히 할 뿐 아니라, 지리적·진화적으로 연관된 분류군을 연구하는 기초 자료로 활용될 수 있으며, 국경과 관계없는 분류군 인식의 불일치 문제 해결에도 이바지하게 되리라 기대한다.

APPENDICES

Appendix Figure 1. Character and character states included in this study



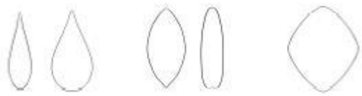
Appendix Figure 1. (Continued)

Cauline leaf

Simple or compound leaf

Leaflets number

Terminal or middle leaflet shape (in the compound leaf)



Petiole length (cm)

Petiole surface

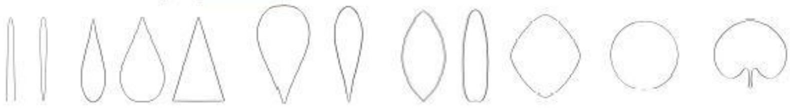
Leaf arrangement

Number of leaves at a node

Leaf length (cm)

Leaf width (cm)

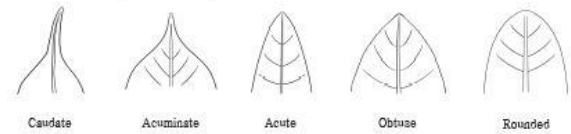
Leaf blade shape



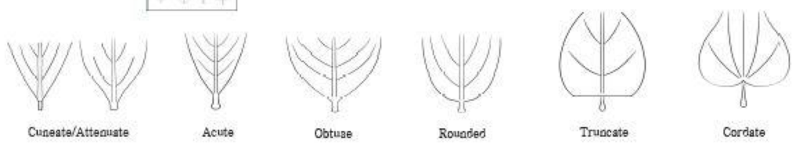
Leaf texture

Appendix Figure 1. (Continued)

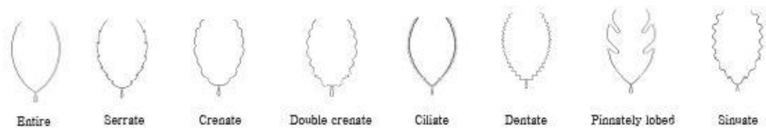
Leaf apex



Leaf base

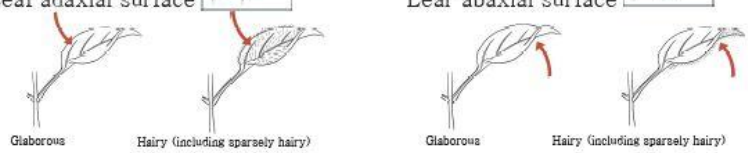


Leaf margin/lobe

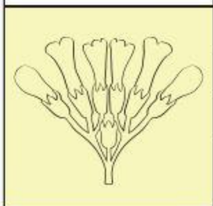


Leaf adaxial surface

Lear abaxial surface



Inflorescence

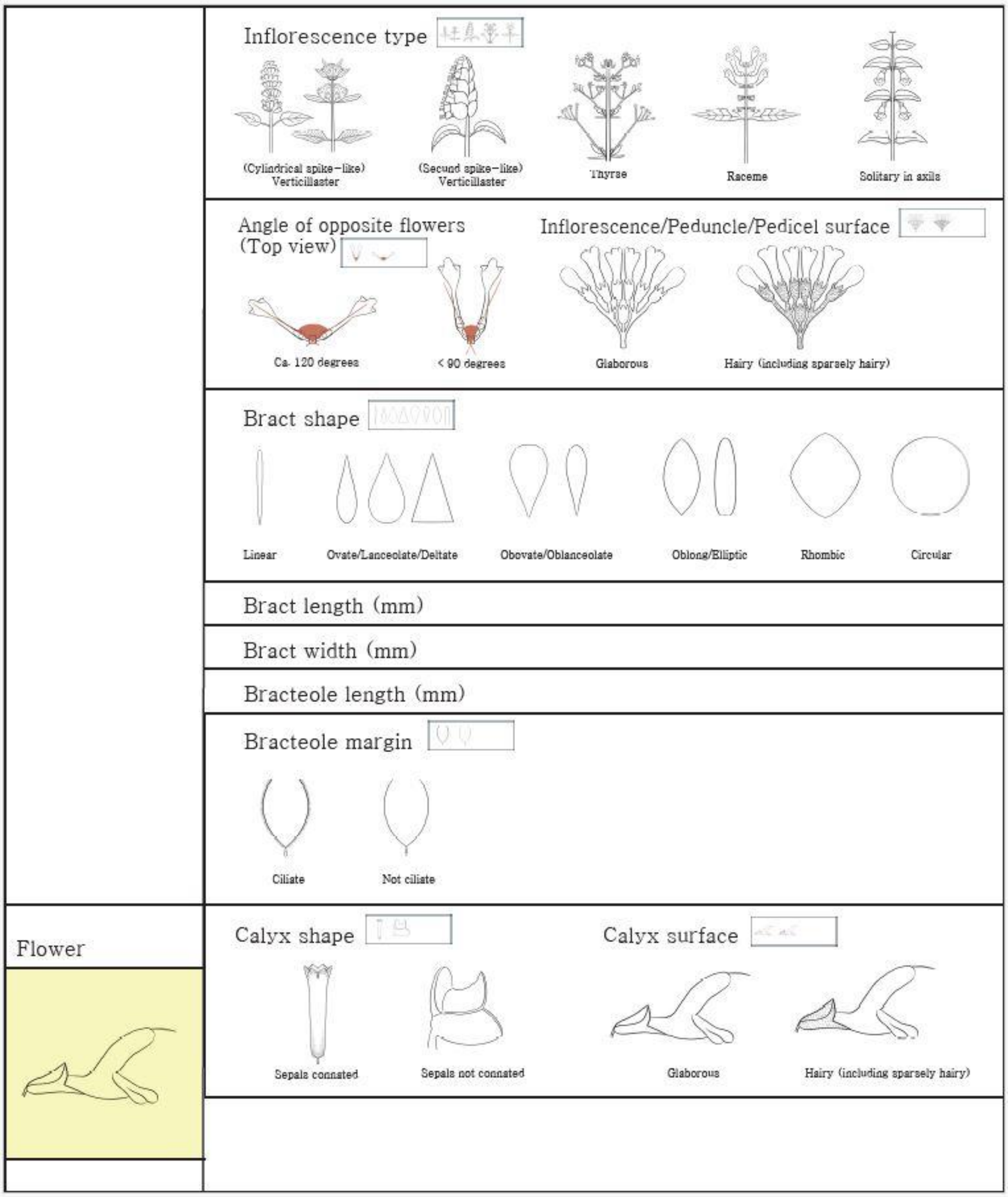


Inflorescence/flower position

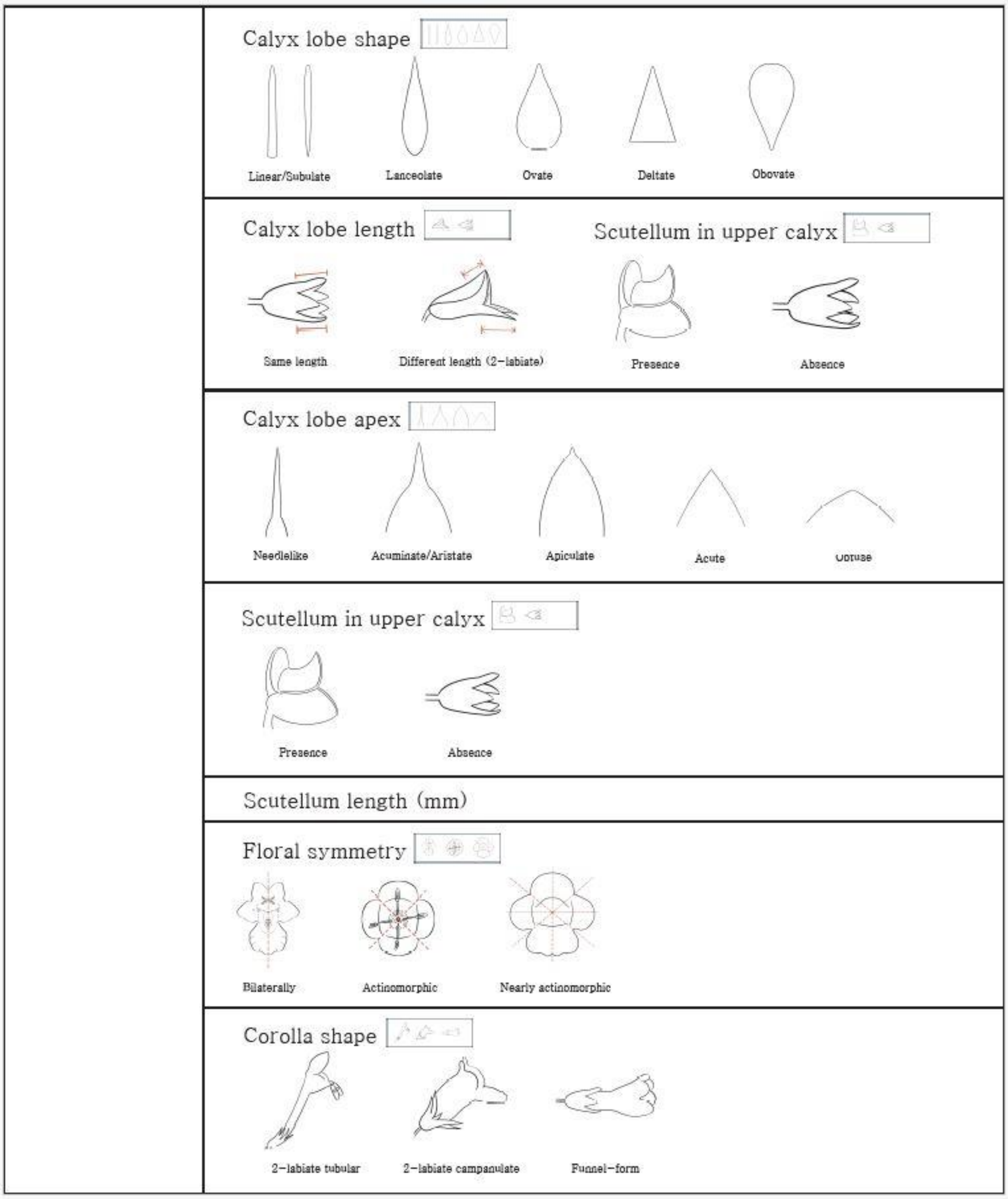
Inflorescence length (cm)

Inflorescence width (cm)

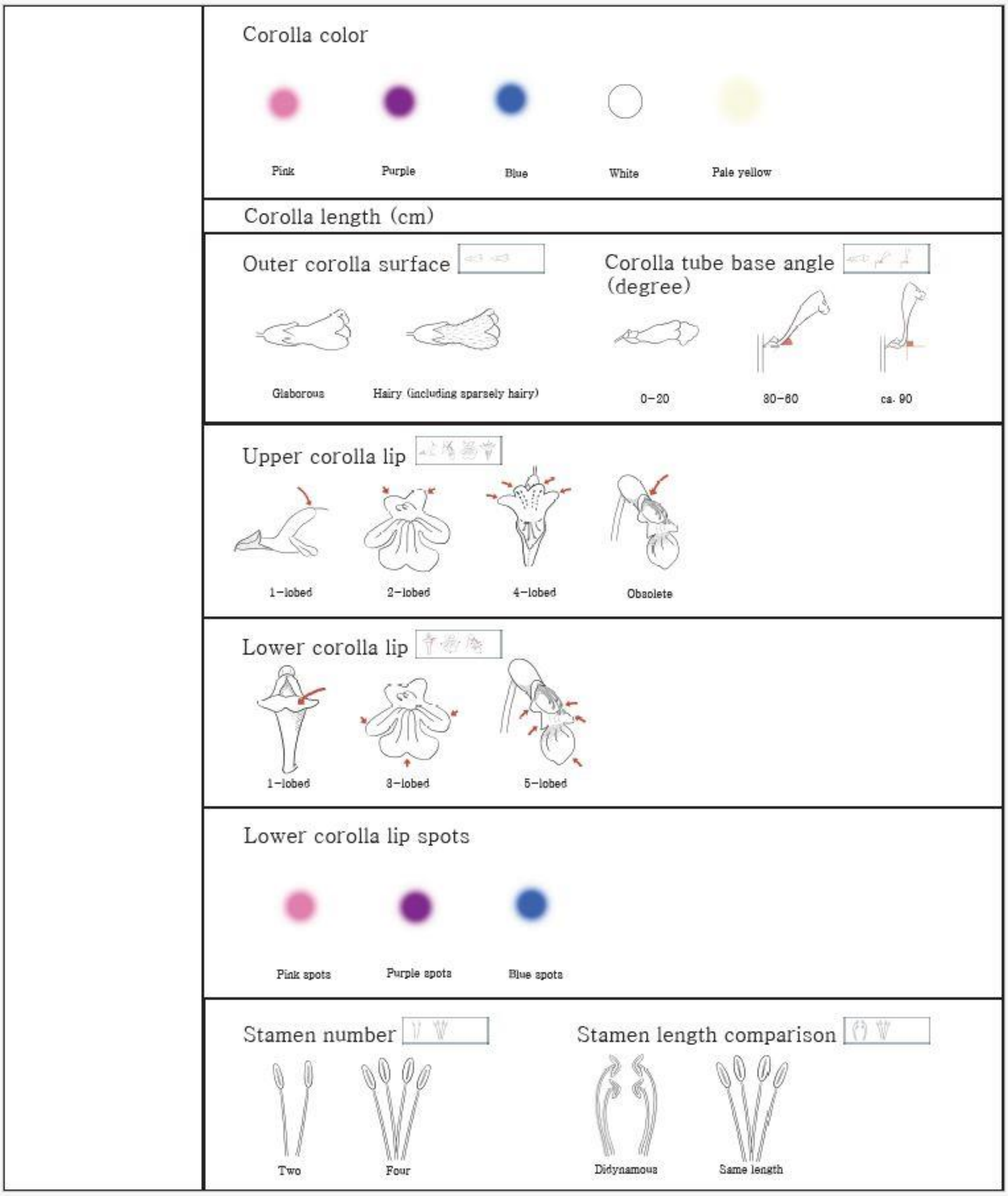
Appendix Figure 1. (Continued)



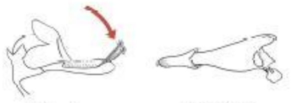
Appendix Figure 1. (Continued)



Appendix Figure 1. (Continued)



Appendix Figure 1. (Continued)

Fruit	Stamen protrusion to corolla  Anther length (mm)
	Fruit appendage 

Appendix Table 1. Voucher specimens for taxa included in this study

No	Scientific name	Collector	Herbarium	Herbarium collection ID
1	*Agastache rugosa* (Fisch. & C.A.Mey.) Kuntze	*H. Suh s. n.*	SWU	SWU0029228
2	*Ajuga decumbens* Thunb.	*H. Moon 2021-93*	SWU	SWU0036798
3	*Ajuga multiflora* Bunge	*M. Chae s. n.*	SWU	SWU0062051
4	*Ajuga spectabilis* Nakai	*J. Suk s. n.*	KH	KHB1516932
5	*Amethystea caerulea* L.	*E. Choi s. n.*	SWU	SWU0020245
6	*Caryopteris incana* (Thunb. ex Houtt.) Miq.	*C. Kim & J. Ahn s. n.*	JNU	DB2004 JNU10603
7	*Tripora divaricata* (Maxim.) P.D.Cantino	*J. Lee et al. s. n.*	KH	KHB1627969
8	*Callicarpa dichotoma* (Lour.) Raeusch. ex K.Koch	*H. Suh 2018-0415*	SWU	SWU0026583
9	*Callicarpa japonica* Thunb.	*H. Moon 2021-206*	SWU	SWU0039686
10	*Callicarpa japonica* Thunb. var. *luxurians* Rehder	*H. Suh s. n.*	SWU	SWU0029148
11	*Callicarpa mollis* Siebold & Zucc.	*S. Kim 2021-173*	SWU	SWU0039894
12	*Clerodendrum trichotomum* Thunb.	*H. Moon 2021-247*	SWU	SWU0039776
13	*Clinopodium gracile* (Benth.) Kuntze	*S. Kim 2010171*	SWU	SWU0014930
14	*Clinopodium micranthum* (Regel) H.Hara	*B. Lee 2015-002*	SWU	SWU0009768
15	*Clinopodium multicaule* (Maxim.) Kuntze	*S. Kim 2021-538*	SWU	SWU0053708
16	*Clinopodium chinense* (Benth.) Kuntze var. *parviflorum* (Kudô) H.Hara	*S. Kim 2010174*	SWU	SWU0014933
17	*Clinopodium chinense* (Benth.) Kuntze var. *shibetchense* (H.Lév.) Koidz.	*Y. Lee s. n.*	SWU	SWU0010434
18	*Dracocephalum argunense* Fisch. ex Link	*N. Lee s. n.*	SWU	SWU0005437
19	*Dracocephalum rupestre* Hance	*S. Kim 2022-107*	SWU	SWU0054891
20	*Elsholtzia ciliata* (Thunb.) Hyl.	*S. Kim 2011288*	SWU	SWU0000624
21	*Elsholtzia angustifolia* (Loes.) Kitag.	*M. Jung s. n.*	SWU	SWU0054978
22	*Elsholtzia minima* Nakai	*D. Kim & S. Kim s. n.*	KH	KHB1430910
23	*Elsholtzia splendens* Nakai ex F. Maek.	*S. Kim 2021-566*	SWU	SWU0053746

Appendix Table 1. (Continued)

No	Scientific name	Collector	Herbarium	Herbarium collection ID
24	*Elsholtzia byeonsanensis* M.Kim	*S. Park 145566*	KH	KHB1577235
25	*Galeopsis bifida* Boenn	*S. Yoo & B. Kim s. n.*	KH	KHB1346814
26	*Glechoma grandis* (A. Gray) Kuprian.	*H. Yun s. n.*	SWU	SWU0029637
27	*Isodon excisus* (Maxim.) Kudô	*Y. Ma 2010038*	SWU	SWU0010119
28	*Isodon japonicus* (Burm.f.) H.Hara	*Y. Ma 2010069*	SWU	SWU0009732
29	*Isodon inflexus* (Thunb.) Kudô var. *canescens* (Nakai) Kudô	*C. Hyun s. n.*	SKK	SKK044099
30	*Isodon serra* (Maxim.) Kudô	*H. Choi s. n.*	SWU	SWU0020444
31	*Isodon inflexus* (Thunb.) Kudô	*Y. Ma 2010072*	SWU	SWU0010166
32	*Lagopsis supina* (Stephan) Ikonn.-Gal. ex Knorring	*S. Yun 094*	KH	KHB1234602
33	*Lamium album* L. subsp. *barbatum* (Siebold & Zucc.) Mennema	*S. Kim 2020-024*	SWU	SWU0036587
34	*Lamium amplexicaule* L.	*M. Jung 2021-010*	SWU	SWU0041897
35	*Lamium album* L.	*H. Lee et al. s. n.*	KH	KHB1582138
36	*Lamium purpureum* L.	*S. Kim & J. Yang s. n.*	SWU	SWU0029494
37	*Lamium takesimense* Nakai	*B. Oh et al. s. n.*	KH	KHB1613769
38	*Leonurus japonicus* Houtt.	*M. Jung 2022-012*	SWU	SWU0054454
39	*Leonurus macranthus* Maxim.	*H. Suh 2018-0806*	SWU	SWU0026998
40	*Lycopus maackianus* (Maxim. ex Herder) Makino	*Y. Kim & H. Kim s. n.*	KH	KHB1434009
41	*Lycopus uniflorus* Michx.	*H. Suh s. n.*	SWU	SWU0029155
42	*Lycopus coreanus* H.Lév.	*S. Kim 2011509*	SWU	SWU0005622
43	*Lycopus lucidus* Turcz. ex Benth. var. *hirtus* Regel	*Y. Kim & H. Chae s. n.*	KH	KHB1434011
44	*Lycopus charkeviczii* Prob.	*J. Byeon & H. Lee s. n.*	KH	KHB1417293
45	*Lycopus lucidus* Turcz. ex Benth.	*B. Oh et al. s. n.*	KH	KHB1609862
46	*Meehania urticifolia* (Miq.) Makino	*H. Moon 2022-103*	SWU	SWU0054557

Appendix Table 1. (Continued)

No	Scientific name	Collector	Herbarium	Herbarium collection ID
47	*Mentha canadensis* L.	*H. Suh 2018-0420*	SWU	SWU0026588
48	*Mosla chinensis* Maxim.	*Y. Chung & M. Han s.n.*	KH	KHB1258255
49	*Mosla dianthera* (Buch.-Ham. ex Roxb.) Maxim.	*S. Kim s. n.*	SWU	SWU0003735
50	*Mosla japonica* (Benth. ex Oliv.) Maxim	*S. Kim 2011145*	SWU	SWU0000480
51	*Mosla scabra* (Thunb.) C.Y.Wu & H.W.Li	*S. Kim s. n.*	SWU	SWU0003756
52	*Nepeta cataria* L.	*H. Park s. n.*	SWU	SWU0042247
53	*Phlomis umbrosa* Turcz.	*M. Jung 2021-100*	SWU	SWU0053083
54	*Pogostemon stellatus* (Lour.) Kuntze	*S. Park 32993*	KH	KHB1034901
55	*Pogostemon yatabeanus* (Makino) Press	*D. Kim & S. Kim s. n.*	KH	KHB1430793
56	*Prunella vulgaris* L. subsp. *asiatica* (Nakai) H.Hara	*S. Lee s. n.*	SWU	SWU0005767
57	*Prunella intermedia* Link	*S. Kim 2011370*	SWU	SWU0000707
58	*Salvia japonica* Thunb.	*B. Oh et al. s. n.*	KH	KHB1480089
59	*Salvia plebeia* R.Br.	*S. Kim 2016-0026*	SWU	SWU010903
60	*Salvia chanryoenica* Nakai	*B. Oh et al. s. n.*	KH	KHB1610552
61	*Scutellaria baicalensis* Georgi	*G. Park s. n.*	SWU	SWU0004448
62	*Scutellaria barbata* D.Don	*H. Jung s. n.*	SWU	SWU0004450
63	*Scutellaria dependens* Maxim.	*C. Choi 2015-0001*	SWU	SWU0010332
64	*Scutellaria indica* L.	*H. Won s. n.*	SWU	SWU0004441
65	*Scutellaria insignis* Nakai	*S. Lee s. n.*	SWU	SWU0004433
66	*Scutellaria pekinensis* Maxim. var. *transitra* (Makino) H.Hara	*M. Lee s. n.*	SWU	SWU0004299
67	*Scutellaria pekinensis* Maxim. var. *ussuriensis* (Regel) Hand.-Mazz	*Y. Suk s. n.*	SWU	SWU0004437
68	*Scutellaria strigillosa* Hemsl.	*S. Kim 20140705-2*	SWU	SWU0006320
69	*Scutellaria guilielmii* A.Gray	*Y. Lee s. n.*	SWU	SWU0060335

Appendix Table 1. (Continued)

No	Scientific name	Collector	Herbarium	Herbarium collection ID
70	*Scutellaria indica* L. var. *coccinea* S.T.Kim & S.T.Lee	*Y. Choi s. n.*	SWU	SWU0010619
71	*Scutellaria indica* L. var. *tsusimensis* (H.Hara) Ohwi	*C.G.Jang et al. s. n.*	KH	KHB1359256
72	*Scutellaria tuberifera* C.Y.Wu & C.Chen	*C. Kim 31383*	WFRC	WTFRC10015663
73	*Scutellaria pekinensis* Maxim. var. *alpina* (Nakai) H.Hara	*G. Park s. n.*	SWU	SWU0004264
74	*Scutellaria pekinensis* Maxim. var. *maxima* S.T.Kim & S.T.Lee	*B. Jung s. n.*	SWU	SWU0004246
75	*Stachys riederi* Cham. var. *japonica* (Miq.) H.Hara	*G. Jin s. n.*	SWU	SWU0021503
76	*Teucrium japonicum* Houtt.	*S. Kim 2015-0137*	SWU	SWU0010067
77	*Teucrium veronicoides* Maxim.	*S. Ji et al. s. n.*	KH	KHB1554496
78	*Teucrium viscidum* Blume var. *miquelianum* (Maxim.) H.Hara	*S. Kim 2021-490*	SWU	SWU0053659
79	*Teucrium viscidum* Blume	*Y. Kim 2010-02734*	HHU	HHU0013818
80	*Thymus quinquecostatus* Čelak.	*Y. Oh & C. Lee s. n.*	SWU	SWU0015409
81	*Vitex negundo* L. var. *incisa* (Lam.) C.B.Clarke	*S. Yoo & G. Kim s. n.*	KH	KHB1531582
82	*Vitex rotundifolia* L.f.	*S. Kim 2021-498*	SWU	SWU0053667

Aknowledgements

감사의 글

수목원의 가드너로 일하며 맴돌던 질문. '종이란 무엇이고 그 경계를 어떻게 설정하는가?' 이 문장으로 시작했다고 해도 과언이 아닌 학업을 마치게 되었습니다. 먼저 분류학의 'ㅂ'도 몰랐던 당돌한 학생을 받아주신 김상태 교수님께 감사드립니다. 덕분에 분류학이라는 분야에 대해, 종이란 무엇인지 고민해 보는 즐거운 기회를 가졌습니다. 식물 분류학은 더 이상 할 게 없다는 이야기에 혼란에 빠진 제게 분류학자로서 조언을 아낌없이 나눠주신 동주 교수님과 문혜경 교수님께도 감사드립니다. 이 의문의 실마리를 알려준 도서관과 두꺼운 철학, 과학책에게도 고맙습니다. 저를 재촉하지도, 화를 내지도 않은 덕분에 제 나름의 해답을 찾을 수 있었습니다. 덕분에 제가 과학의 영역 중에서도 생물을 좋아하고, 식물 중에서도 분류학에 끌렸는지 알아갔고, 분류학자로서 발을 내디딘 저를 긍정할 수 있게 되었습니다.

그리고 마음이 척박해질 때마다 저를 지탱해 주었던 야외포지와 생육실의 식물들에게도 감사의 인사를 전합니다. 식물을 살피는 일은 업무이기 이전에 제 마음을 돌보는 시간이었다는 것을 누구보다 잘 알게 되었습니다. 덕분에 가드너 손연주가 살아있을 수 있었습니다. 그리고 살아있는 정원 아래에 있는 방대한 종이 정원에서 꿀풀과 식물을 마음껏 관찰하고 탐닉할 수 있었음에 감사드립니다. 선배 연구원들과 현재 대학원생들의 노력이 없었다면 제

연구를 시작할 수 없었을 것입니다. 덕분에 과거와 현재를 상상하며 연구를 꿈꿀 수 있었습니다.

무엇보다 이방인이었을 저를 따뜻하게 맞아준 랩실 친구들에게 고맙습니다. 저보다 먼저 사초속 식물의 대화형 검색표를 만든 민경이의 조언이 없었다면 제 졸업은 바람 앞의 등불처럼 위태로웠을 것입니다. 매일 점심을 함께 먹으며 연구에 구체적인 조언과 응원을 아낌없이 해주었던 현지와 세은이, 외로운 학위 과정에 함께 해준 졸업 동기 지은이에게도 고맙습니다. 또 같은 방에서 늘 활기찬 에너지로 맞이해준 정우와 주말 연구 메이트였던 바질 엄마 지예에게도 고맙습니다. 지예의 바질이 무사히 겨울을 보내길 바랍니다. 그리고 아쉽게도 만남은 짧았지만 따뜻하게 맞이해주었던 승연이, 소윤이 보라에게도 감사의 인사를 전합니다. 모두의 연구가 순탄히 끝나고, 또 다른 멋진 다음이 있길 진심으로 응원하겠습니다.

끝으로 인간 손연주를 지탱해 준 친구들과 가족들에게 감사합니다. 각기 다른 환경에서 서로의 이야기에 공감하고 배려하는 것은 과거에도 앞으로도 쉬운 일이 아니겠지만, 우정과 사랑으로 극복할 수 있었고, 앞으로도 그러리라 믿습니다. 저 역시 다정이 닳지 않도록 노력하겠습니다.