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# Causes of *Coreopsis basalis* and *Coreopsis lanceolata* Misidentification in Korea and Species Differentiation through Genetic Analysis

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## ABSTRACT

Unregulated trade of ornamental plants greatly increases the risk of species misidentification and ecological invasion. In Korea, *Coreopsis lanceolata*, a perennial species with high invasive potential, is widely distributed under the name *Coreopsis basalis*, which refers to an annual species with comparatively lower ecological risk. To address this issue, we examined national seed import records and conducted chloroplast DNA barcode analyses (*rbcL* and *matK*) of seeds sold as *C. basalis*. Import data revealed that most records were reported only at the genus level (*Coreopsis* spp.) without species-level verification. Molecular analyses further confirmed that all commercial "Geumgyegook (*C. basalis*)" seeds were genetically identical to Chinese populations of "Keungeumgyegook (*C. lanceolata*)," indicating that persistent misidentification stems from institutional shortcomings rather than taxonomic error. To prevent further spread of alien *Coreopsis* spp. and improve invasive species management in Korea, we propose strengthening species-level verification and implementing DNA barcode-based quarantine for seeds of alien plants designated as ecosystem-disturbing, potentially harmful, or import-alert species and those ranked Level 2 or higher in ecological risk assessments. Additionally, we recommend revising the seed import reporting system in cooperation with the Korea Seed & Variety Service and conducting a nationwide reassessment of coreopsis distribution. Further phylogenetic studies on diverse taxa within this genus are necessary to establish more precise management strategies.

**Keywords:** *Coreopsis basalis, Coreopsis lanceolata*, DNA barcoding, Genetic techniques, Invasive species, Misidentification

## Introduction

Global economic growth and aviation industry expansion have accelerated the global spread of alien species, posing a serious threat to biodiversity conservation (Hulme, 2009; Spear *et al*., 2013). Owing to their high ecological adaptability, certain alien plants successfully establish populations in new environments and often outcompete native species, thereby altering community structures and destabilizing ecosystems (Diez *et al*., 2012). Numerous alien plants have been introduced in Korea, exerting both direct and indirect ecological impacts.

*Coreopsis lanceolata* is one of the most widely distributed alien plants in Korea. Its showy yellow flowers and extended flowering period have led to frequent use in landscaping by individuals, municipalities, and public institutions. However, naturalized populations outside of

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intentional planting sites have been increasingly observed (National Institute of Ecology, 2023). The National Institute of Ecology has classified *C. lanceolata* as a Level 2 invasive species due to its high potential for widespread expansion. Although the Ministry of Environment issued a recommendation against its planting, cultivation has continued nationwide, expanding its occupied area.

According to research conducted in China, *C. lanceolata* thrives in various disturbed sites, such as roadsides, farmland margins, and fallow lands, and its strong clonal growth confers high environmental adaptability (Zeng *et al*., 2012). In some regions, this species has already gained a competitive advantage over native plants, forming communities and exhibiting large-scale expansion.

In Japan, *C. lanceolata* competes with native riparian vegetation for light and space (Saito & Okubo, 2013). Owing to its ecological characteristics and invasive potential, *C. lanceolata* was designated as an Invasive Alien Species under the Invasive Alien Species Act in February 2006. Consequently, its cultivation, storage, transportation, and importation have been restricted, and the National Institute for Land and Infrastructure Management (2011), under the Ministry of Land, Infrastructure, Transport and Tourism, issued a removal and control manual.

In Korea, *C. lanceolata* is often confused with *Coreopsis basalis*, an annual herb native to North America, owing to their similar morphologies. However, their ecological traits differ markedly; while *C. lanceolata* is a perennial with a strong reproductive capacity and prolific seed production, which confer high invasive potential (Arifin & Okamoto, 2023; Folgate & Scheiner, 1992), *C. basalis* poses a relatively low ecological risk. Despite these differences, both species are distributed in Korea with the same label "Geumgyegook (*C. basalis*)," leading to frequent mislabeling and misplanting of *C. lanceolata* as *C. basalis*.

In this study, we aimed to identify the root causes of persistent coreopsis misidentification. To this end, we examined the taxonomic units used during the seed importation process and investigated commercial seed distribution records. In addition, we subjected seedlings grown from seeds marketed domestically as *C. basalis* to *rbcL* and *matK* sequence analyses and compared the results with reference sequences of *C. basalis* and *C. lanceolata* in the National Center for Biotechnology Information (NCBI) GenBank and National Institute of Biological Resources (NIBR) databases.

Through these approaches, we sought to elucidate the underlying factors driving the misidentification of *C. lanceolata* as *C. basalis* and provide scientific verification of species identity for seeds mislabeled and distributed as *C. basalis* in Korea.

## Materials and Methods

To verify whether *C. lanceolata* was misidentified as *C. basalis*, we first examined the seed distribution records from the Korea Seed & Variety Service (KSVS). Using the "Production, Import, and Sales Notification of Varieties" function within the KSVS seed distribution-management system (https://www.seed.go.kr/seed/index.do), we retrieved the declaration records for both species. This integrated national platform records all notifications related to the importation and production of horticultural, floricultural, crop, fruit, and genetically modified organism seeds. In the present study, we used these data to confirm the official distribution of *C. basalis* and *C. lanceolata* seeds.

For molecular verification, seeds labeled as *C. basalis* were purchased from ten different specialized seed vendors, all operating online. All purchased seed packages were labeled with the identical product name "Geumgyegook (*C. basalis*)." Germination was conducted in sterilized Petri dishes lined with sterile cotton that was moistened with distilled water. The dishes were evenly seeded and placed in a growth chamber under controlled conditions of 25°C, a constant relative humidity, and an 8 hours photoperiod. Young seedlings obtained 7-10 days after germination were used as the experimental material.

Genomic DNA was extracted from ten leaf samples using the Clear-S™ Quick DNA Extraction Kit (InvirusTech, Gwangju, Korea), following the manufacturer's instructions. The extracted DNA (20 ng) was used as a template for polymerase chain reaction (PCR) amplification of *rbcL* and *matK*. The *rbcL* gene was amplified using the primers *rbcL*-F (5'-ATGTCACCACAAACAGAAAC-3') and *rbcL*-R (5'-TCGCATGTACCYGCAGTTGC-3'). The PCR reactions were performed with a C1000 Touch™ Thermal Cycler (Bio-Rad, Hercules, CA, USA) under the following conditions: an initial denaturation at 95°C for 10 minutes, followed by 35 cycles of denaturation at 95°C for 30 seconds, annealing at 55°C for 30 seconds, and extension at 72°C for 1 minute, with a final extension at 72°C for 5 minutes. For *matK* amplification, we used the primers MatK-1RKIM-f (5'-ACCCAGTCCATCTGGAAATCTTGGTTC-3') and MatK-3FKIM-r (5'-CGTACAGTACTTTTGTGTTTACGAG-3') (Shaikhali *et al*., 2008) under similar conditions, with minor optimization as needed. The PCR products were confirmed through electrophoresis using 1.5% agarose gels and visualized under UV illumination. The amplified products were purified and subjected to Sanger sequencing (Bionics, Seoul, Korea).

The Consortium for the Barcode of Life Plant Working Group recommends *rbcL* and *matK* as standard DNA barcodes for plants (CBOL Plant Working Group, 2009); thus, both markers were analyzed in this study. However, *rbcL*, which evolves relatively slowly, was used primarily as

**Table 1.** Search results from the Korea Seed & Variety Service "Notification of Production, Import, and Sale of Varieties" (*Coreopsis basalis*)

| Certificate number | Seed name | Certificate number | Seed name | Certificate number | Seed name | Certificate number | Seed name |
|---|---|---|---|---|---|---|---|
| 04-0218-1999-1 | Geumgyegook.spp. (*Coreopsis* spp.) | 04-0218-2009-1 | Geumgyegook.spp. (*Coreopsis* spp.) | 04-0218-2013-2 | Geumgyegook.spp. (*Coreopsis* spp.) | 04-1019-2017-1 | Geumgyegook.spp. (*Coreopsis* spp.) |
| 04-0218-1999-2 | Geumgyegook.spp. (*Coreopsis* spp.) | 04-0218-2009-2 | Geumgyegook.spp. (*Coreopsis* spp.) | 04-0218-2014-1 | Geumgyegook.spp. (*Coreopsis* spp.) | 04-1019-2018-1 | Geumgyegook.spp. (*Coreopsis* spp.) |
| 04-0218-1999-3 | Geumgyegook.spp. (*Coreopsis* spp.) | 04-0218-2009-3 | Geumgyegook.spp. (*Coreopsis* spp.) | 04-0218-2014-10 | Geumgyegook.spp. (*Coreopsis* spp.) | 04-1019-2021-1 | Geumgyegook.spp. (*Coreopsis* spp.) |
| 04-0218-1999-4 | Geumgyegook.spp. (*Coreopsis* spp.) | 04-0218-2009-4 | Geumgyegook.spp. (*Coreopsis* spp.) | 04-0218-2014-11 | Geumgyegook.spp. (*Coreopsis* spp.) | 04-1019-2022-1 | Geumgyegook.spp. (*Coreopsis* spp.) |
| 04-0218-1999-5 | Geumgyegook.spp. (*Coreopsis* spp.) | 04-0218-2009-5 | Geumgyegook.spp. (*Coreopsis* spp.) | 04-0218-2014-12 | Geumgyegook.spp. (*Coreopsis* spp.) | 04-1019-2022-2 | Geumgyegook.spp. (*Coreopsis* spp.) |
| 04-0218-2004-1 | Geumgyegook.spp. (*Coreopsis* spp.) | 04-0218-2009-6 | Geumgyegook.spp. (*Coreopsis* spp.) | 04-0218-2014-2 | Geumgyegook.spp. (*Coreopsis* spp.) | 04-1019-2022-3 | Geumgyegook.spp. (*Coreopsis* spp.) |
| 04-0218-2004-2 | Geumgyegook.spp. (*Coreopsis* spp.) | 04-0218-2009-7 | Geumgyegook.spp. (*Coreopsis* spp.) | 04-0218-2014-3 | Geumgyegook.spp. (*Coreopsis* spp.) | 04-1019-2025-1 | Geumgyegook.spp. (*Coreopsis* spp.) |
| 04-0218-2004-3 | Geumgyegook.spp. (*Coreopsis* spp.) | 04-0218-2010-1 | Geumgyegook.spp. (*Coreopsis* spp.) | 04-0218-2014-4 | Geumgyegook.spp. (*Coreopsis* spp.) | 04-1020-2017-1 | Geumgyegook (*Coreopsis basalis*) |
| 04-0218-2004-4 | Geumgyegook.spp. (*Coreopsis* spp.) | 04-0218-2010-2 | Geumgyegook.spp. (*Coreopsis* spp.) | 04-0218-2014-5 | Geumgyegook.spp. (*Coreopsis* spp.) | 04-1020-2018-1 | Geumgyegook (*Coreopsis basalis*) |
| 04-0218-2005-1 | Geumgyegook.spp. (*Coreopsis* spp.) | 04-0218-2010-3 | Geumgyegook.spp. (*Coreopsis* spp.) | 04-0218-2014-6 | Geumgyegook.spp. (*Coreopsis* spp.) | 04-1020-2020-1 | Geumgyegook (*Coreopsis basalis*) |
| 04-0218-2005-2 | Geumgyegook.spp. (*Coreopsis* spp.) | 04-0218-2010-4 | Geumgyegook.spp. (*Coreopsis* spp.) | 04-0218-2014-7 | Geumgyegook.spp. (*Coreopsis* spp.) | 04-1020-2021-1 | Geumgyegook (*Coreopsis basalis*) |
| 04-0218-2005-3 | Geumgyegook.spp. (*Coreopsis* spp.) | 04-0218-2010-5 | Geumgyegook.spp. (*Coreopsis* spp.) | 04-0218-2014-8 | Geumgyegook.spp. (*Coreopsis* spp.) | 04-1020-2021-2 | Geumgyegook (*Coreopsis basalis*) |
| 04-0218-2005-4 | Geumgyegook.spp. (*Coreopsis* spp.) | 04-0218-2011-1 | Geumgyegook.spp. (*Coreopsis* spp.) | 04-0218-2014-9 | Geumgyegook.spp. (*Coreopsis* spp.) | 04-1020-2021-3 | Geumgyegook (*Coreopsis basalis*) |
| 04-0218-2005-5 | Geumgyegook.spp. (*Coreopsis* spp.) | 04-0218-2011-2 | Geumgyegook.spp. (*Coreopsis* spp.) | 04-0218-2015-1 | Geumgyegook.spp. (*Coreopsis* spp.) | 04-1020-2022-1 | Geumgyegook (*Coreopsis basalis*) |
| 04-0218-2006-1 | Geumgyegook.spp. (*Coreopsis* spp.) | 04-0218-2012-1 | Geumgyegook.spp. (*Coreopsis* spp.) | 04-0218-2015-2 | Geumgyegook.spp. (*Coreopsis* spp.) | 04-1020-2023-1 | Geumgyegook (*Coreopsis basalis*) |
| 04-0218-2006-2 | Geumgyegook.spp. (*Coreopsis* spp.) | 04-0218-2012-2 | Geumgyegook.spp. (*Coreopsis* spp.) | 04-0218-2015-3 | Geumgyegook.spp. (*Coreopsis* spp.) | - | |
| 04-0218-2007-1 | Geumgyegook.spp. (*Coreopsis* spp.) | 04-0218-2012-3 | Geumgyegook.spp. (*Coreopsis* spp.) | 04-0218-2015-4 | Geumgyegook.spp. (*Coreopsis* spp.) | - | |
| 04-0218-2007-2 | Geumgyegook.spp. (*Coreopsis* spp.) | 04-0218-2013-1 | Geumgyegook.spp. (*Coreopsis* spp.) | 04-0218-2016-1 | Geumgyegook.spp. (*Coreopsis* spp.) | - | |

-, not applicable.

a reference for cross-comparison with *rbcL* sequences of *C. basalis* and *C. lanceolata* available in the NCBI GenBank and NIBR databases. In contrast, *matK*, which exhibits higher variability, was used as the primary marker for species-level discrimination.

Sequence alignments were performed using the ClustalW algorithm in MEGA12 (Kumar *et al*., 2024). Phylogenetic analyses were conducted using the maximum likelihood method in MEGA12 by applying the general time-reversible substitution model. Rate heterogeneity was modeled using a discrete gamma distribution with five categories (+G), assuming no invariant sites (+I=0.00%). Gamma distribution parameters were set to 0.0479 for *rbcL* and 200.0000 for *matK*.

We analyzed 533 bp of *rbcL* (including codon positions 1, 2, and 3 along with non-coding regions) and 657 bp of *matK* sequences. Initial trees were generated from distance matrices using the neighbor-joining method (Saitou & Nei, 1987), and branch support was assessed using 1,000 bootstrap replications (Felsenstein, 1985).

## Results and Discussion

### Distribution and importation status of *Coreopsis basalis* and *Coreopsis lanceolata* seeds

Under the Seed Industry Act of Korea, any party intending to produce, import, or sell seeds of registered plant varieties must submit an application to the KSVS, including the official varietal name and seed samples. A review of the KSVS "Notification of Production, Import, and Sale of Varieties" database revealed no records registered under the species name *C. lanceolata* and only eight cases registered under the name *C. basalis* (Table 1). In contrast, imports listed under the generic designation "*Coreopsis* spp." amounted to 69 cases between 1999 and 2025.

These results indicate that seed imports were more commonly reported at the genus level than at the species level. Consequently, a substantial proportion of seeds distributed under the Korean vernacular name "Geumgyegook" may have actually been "Keungeumgyegook (*C. lanceolata*)" seeds. Notably, *Coreopsis* spp. are taxonomically diverse, comprising 30 species, 18 varieties, and 4 forms (52 taxa in total) in eastern North America (Sherff, 1955; Smith, 1976) and over 130 taxa worldwide. Despite this diversity, seed importation and distribution in Korea have only been managed at the genus level, underscoring a systemic deficiency that may contribute to frequent misidentification at the species level.

Hulme (2009) highlighted pathway management as a central principle for controlling invasive species. The present findings indicate possible deficiencies in pathway management within Korea's current institutional framework. Thus, the persistent misidentification of *C. lanceolata* as *C. basalis* may be rooted in the structural weaknesses of the regulatory system.

### Genetic analysis of *Coreopsis basalis*

To verify whether the seeds distributed under the Korean vernacular name "Geumgyegook (*C. basalis*)" were indeed *C. basalis*, seeds were purchased from ten specialized seed retailers across Korea, each representing a different distributor (Table 2).

The purchased seeds were germinated under controlled conditions, and young seedlings were obtained for use as the experimental material. Subsequently, molecular phylogenetic analyses were performed to assess the genetic relationships between the collected samples. All seed lots used in this study were explicitly labeled on product packaging and sales information at the time of purchase as "Korean name: Geumgyegook, Scientific name: *C. basalis*." Therefore, genetic analyses were performed exclusively on seeds sold under this specific designation.

Genetic analyses were conducted using the chloroplast genes *rbcL* and *matK*. For the *rbcL* locus, 10 sequences were obtained from the seedlings. In addition, seven sequences of *C. lanceolata* were retrieved from GenBank, and four sequences of *C. lanceolata* were obtained from the NIBR database. To include congeneric and related taxa, the dataset also included one sequence of *C. basalis*, two sequences of *Coreopsis tinctoria*, and one sequence of *Helianthus annuus* (Asteraceae), with the latter serving as the outgroup. In total, 25 *rbcL* sequences were used for phylogenetic analysis.

For the *matK* locus, eight sequences were obtained from the seedlings, while four *C. lanceolata* sequences were retrieved from GenBank, and one *C. lanceolata* se-

**Table 2.** Purchased *Coreopsis basalis* seed list

| No. | Seed provider | Seed name | No. | Seed provider | Seed name |
|---|---|---|---|---|---|
| 1 | Gapjone | Geumgyegook | 6 | Hannong Mart | Geumgyegook |
| 2 | Garamwon | Geumgyegook | 7 | Seedling of Dongkook | Geumgyegook |
| 3 | Namheung Garden | Geumgyegook | 8 | On Seed | Geumgyegook |
| 4 | Market of Sandeul | Geumgyegook | 9 | Korea Falm | Geumgyegook |
| 5 | Joojoo Seed | Geumgyegook | 10 | World Seed Mall | Geumgyegook |

quence was obtained from the NIBR database. The dataset was further supplemented with one sequence of *C. basalis*, two sequences of *C. tinctoria*, and one sequence of *H. annuus* (outgroup). In total, 17 *matK* sequences were analyzed for phylogenetic reconstruction (Table 3).

*Phylogenetic analysis based on rbcL*

Phylogenetic analysis using the *rbcL* locus revealed no discriminatory power among the examined sequences (Fig. 1). This finding indicates that *rbcL* is not an appropriate marker for resolving relationships among *Coreopsis* spp. These results are consistent with those of previous studies (CBOL Plant Working Group, 2009; Hollingsworth *et al*., 2009), which demonstrated that while *rbcL* is suitable for phylogenetic inference at the genus or family level, it has limited resolution for distinguishing closely related species (Leaks *et al*., 2025).

*Phylogenetic analysis based on matK*

Phylogenetic analysis using the *matK* locus revealed that the eight sequences obtained from the seedlings were clustered within the same clade as *C. lanceolata* accessions from China available in GenBank (Fig. 2). This result indicates that the seeds currently distributed and sold in Korea under the name "Geumgyegook (*C. basalis*)" are in fact derived from Chinese populations of *C. lanceolata*.

Although the analyzed species did not form distinct monophyletic groups but rather exhibited non-monophyly within a single clade, indicating the need for further phylogenetic studies, the shared population structure of *C. lanceolata* was nevertheless clearly identifiable.

These findings demonstrate that seeds imported under the genus-level designation "*Coreopsis* spp." were subsequently packaged and sold under the species-level name "*C. basalis*." However, genetic evidence confirmed that these seeds were actually *C. lanceolata*. As a result, plants cultivated nationwide under the name "Geumgyegook (*C. basalis*)" are actually misidentified populations of "Keungeumgyegook (*C. lanceolata*)."

Future efforts to obtain accurate genetic information for *C. basalis*, coupled with expanded phylogenetic research within *Coreopsis* spp., are required to clarify the taxonomic relationships among the species currently cultivated in Korea.

**Causes and ecological implications of misidentification**

In this study, we determined that the persistent misidentification of *C. lanceolata* as *C. basalis* originated from the import reporting system, in which species-level verification was omitted. This issue is not merely taxonomic; it also has serious implications for ecosystem management and invasive species policies.

First, the practice of importing seeds under genus-level designations has resulted in nationwide planting of *C. lanceolata* under the name *C. basalis*, thereby increasing the potential for ecological disturbance. Notably, *C. lanceolata* possesses traits such as an extended flowering period and a high reproductive capacity, which may enable it to outcompete native flora (Diez *et al*., 2012; National Institute of Ecology, 2023).

Second, repeated large-scale introductions can enhance genetic diversity and, consequently, increase the invasive potential of alien species. The repeated importation of Chinese *C. lanceolata* lineages, as confirmed in the present study, poses a potential risk that may accelerate local adaptation and expansion in Korea.

Third, although *Coreopsis* spp. have high ornamental value and are widely favored for landscaping (Hind *et al*., 2023), the absence of accurate species-level identification creates systemic blind spots in invasive species management.

**Table 3.** Sample information and sequence identifiers (GenBank accession numbers and NIBR numbers) used in this study

| Species | Gene region | Sequence identifiers | Source |
|---|---|---|---|
| *Coreopsis lanceolata* | *matK* | AY551495.1, MN273582.1, MK435701.1, PV694530.1/WBN0007886 | GenBank/NIBR |
| | *rbcL* | MN185072.1, MN204733.1, OL537597.1, MG224472.1, MG222413.1, HM849915.1, PV694530.1/WBN0395060, WBN0361080, WBN0361079, WBN0007887 | GenBank/NIBR |
| *Coreopsis basalis* | *matK* | AY551492.1 | GenBank |
| | *rbcL* | KJ773398.1 | GenBank |
| *Coreopsis tinctoria* | *matK* | MH551963.1, HM989735.1 | GenBank |
| | *rbcL* | KY627146.1, MG222247.1 | GenBank |
| *Helianthus annuus* | *matK* | OQ847530.1 | GenBank |
| | *rbcL* | MF688968.1 | GenBank |

NIBR, National Institute of Biological Resources.

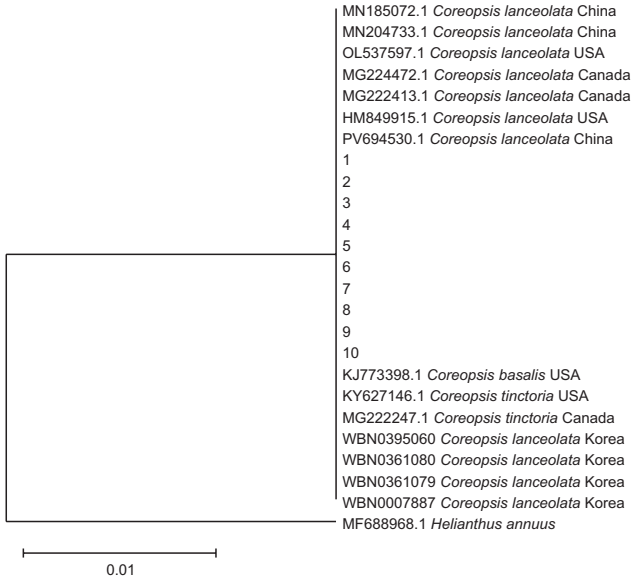


**Fig. 1.** A maximum likelihood phylogenetic tree was reconstructed based on the *rcbL* gene sequences of *Helianthus annuus* (Asteraceae) and *Coreopsis* spp.

## Conclusion

This study provides scientific evidence that the persistent misidentification of *C. lanceolata* as *C. basalis* arises not from simple taxonomic errors but rather from systemic limitations in the regulatory framework. Because genus-level declarations are permitted at the import stage, *C. lanceolata* is erroneously distributed nationwide under the name *C. basalis*, thereby creating a major pathway for the spread of this alien species. Through DNA barcode analyses, we confirmed that commercial seeds sold as "Geumgyegook (*C. basalis*)" in Korea were in fact Chinese lineages of "Keungeumgyegook (*C. lanceolata*)."

Accordingly, we recommend the following measures:

1. Mandatory species-level verification and DNA barcode-based quarantine for seeds of alien plants designated as ecosystem-disturbing species, potentially harmful species, species under import alert, or species ranked at Level 2 or higher in ecological risk assessments.
2. Revision of the seed importation reporting system in coordination with the KSVS to ensure species-level accuracy for alien plant seeds.
3. Nationwide reassessment of *Coreopsis* spp. distribution to clarify the current extent of misidentified plantings.

These measures are essential not only for regulating the importation and distribution of alien plants but also for fundamentally improving Korea's broader system of alien species management, thereby contributing to long-term ecological stability.

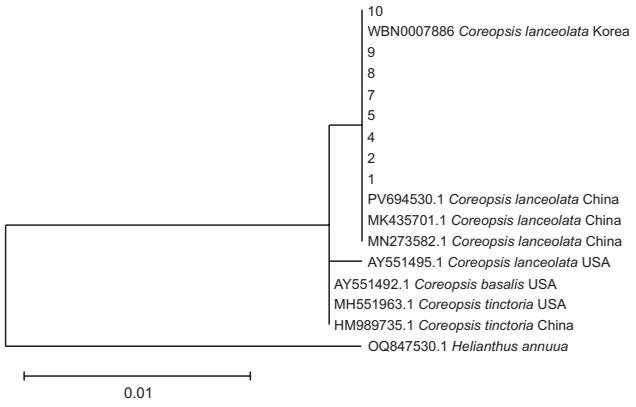


**Fig. 2.** Maximum likelihood phylogenetic tree was reconstructed based on the *matK* gene sequences of *Helianthus annuus* (*Asteraceae*) and *Coreopsis* spp.

## Author Contributions

Conceptualization: KHP. Data curation: KHP, IJA. Formal analysis: KHP, IJA. Funding acquisition: KHP. Investigation: KHP, IJA. Methodology: KHP. Project administration: KHP. Resources: KHP. Software: IJA. Supervision: KHP. Validation: KHP. Visualization: KHP, IJA. Writing – original draft: KHP. Writing – review & editing: KHP.

## Conflict of Interest

The authors declare that they have no competing interests.

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