

ARTICLE

Competition between pink muhly grass and native plant species: Is it really a harmful invasive species?

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Abstract

Pink muhly grass (*Muhlenbergia capillaris* Trin.) is an exotic species in South Korea and is popular worldwide as an ornamental grass for landscaping purposes. The Ministry of Environment in South Korea has categorized this species as an “Ecosystem Hazard Class 2” plant, requiring long-term monitoring to assess its ecological impacts on native species and communities. In this study, a 2-year greenhouse experiment was conducted using *M. capillaris* and 17 native plant species (6 annuals, 8 nonwoody perennials, and 3 woody perennials) to test the hypothesis that if *M. capillaris* is an invasive species, it will negatively affect the establishment and growth of native plants in competitive pairings compared with controls (native species grown in monoculture). Results showed that the mean canopy cover of native plants in competition with *M. capillaris* was not significantly different from monocultures of the corresponding native species. There were also no significant differences in mean aboveground biomass production between native species growing with *M. capillaris* compared to corresponding native monocultures. Results indicate that *M. capillaris* did not significantly affect the establishment and growth of the 17 native species investigated. The minimal impacts suggest that *M. capillaris* may not be a harmful invasive species, but further monitoring of its spread will be required to test these findings under natural conditions.

KEYWORDS

additive design, establishment and growth, greenhouse experiment, invasion impact, invasive species management, landscaping plant, monoculture and competition, *Muhlenbergia capillaris*, plant competition

INTRODUCTION

Pink muhly grass (*Muhlenbergia capillaris* Trin.) is a monocotyledonous perennial grass of the family Poaceae native to the United States. It is classed as endangered in several US states including Connecticut, Indiana, Maryland, and New Jersey (Energy and Protection, 2010),

but concurrently, it is also very popular worldwide for use in landscaping (Chang et al., 2021). For example, in South Korea, the landscape coverage of this species now exceeds 100,000 m². It was first introduced to South Korea in 2014 in an ecological park on Jeju Island for landscape purposes. It was also voted as the plant of the year 2012 by the Garden Club of America. The Ministry of

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Environment in South Korea has categorized *M. capillaris* as an “Ecosystem Hazard Class 2” plant, meaning that long-term monitoring is required to assess its ecological impacts on native communities (National Institute of Ecology, 2019). The ministry has also recommended no further planting of the species for landscaping because of uncertainty about potential negative impacts on local natural ecosystems. Plant species introduced for horticultural purposes may become invasive and difficult to manage (Bhagwat et al., 2012; Mungi et al., 2020; Reichard & White, 2001). It is therefore timely and important to assess the possible ecological impacts of *M. capillaris* on native plant species.

A modeled habitat suitability map for *M. capillaris* (Park et al., 2020) predicts highest distribution in the temperature range of 12–24°C and precipitation of 800–1300 mm, corresponding to the southern coastline of the Korean peninsula. Although the model predicts that potential distribution will be limited rather than nationwide, it is still uncertain whether *M. capillaris* will become a harmful invasive species able to alter the composition of native plant communities.

This study, conducted over a 2-year period, reports the first experimental test of competition between *M. capillaris* and 17 native plant species. The underlying hypothesis was that if *M. capillaris* is a harmful invasive species, it will suppress the establishment and growth of native plants in competitive treatments, with the magnitude of effects varying according to species.

MATERIALS AND METHODS

Experimental setup and seed preparation

A pot experiment was set up in the greenhouse facility of the Department of Biological Sciences and Biotechnology at Andong National University. The experiment was designed to simulate a scenario in which seeds of *M. capillaris* reach bare soil containing seeds of native species.

The 17 native species tested against *M. capillaris* are shown in Table 1. These 17 species were selected based on their nativeness to the study area (South Korea), habitat preference (shared with *M. capillaris*), seed availability (local seed suppliers), and germination rate (>5%). The species nomenclature in this paper is that used in PLANT List (<http://www.theplantlist.org>) and World Flora Online (www.worldfloraonline.org), which shows the accepted species names as determined by the Flora of Korea Editorial Committee (2007).

Seeds of *M. capillaris* and of native plants were purchased from seed suppliers in 2020. To determine seed viability, all seeds were cold stratified at 3°C, as described by Byun et al. (2013, 2020). To test seed germination,

TABLE 1 Native species tested in this study.

Categories	Species
Annuals (6) (including grasses and forbs)	<i>Lactuca indica</i> L., <i>Xanthium strumarium</i> Lour., <i>Glycine max</i> subsp. <i>soja</i> (Siebold & Zucc.) H. Ohashi, <i>Chenopodium giganteum</i> D. Don, <i>Elsholtzia splendens</i> Nakai ex Maekawa, and <i>Portulaca oleracea</i> L.
Herbaceous perennials (8)	<i>Miscanthus sinensis</i> Andersson, <i>Phragmites australis</i> (Cav.) Steud., <i>Artemisia indica</i> Willd., <i>Pennisetum alopecuroides</i> (L.) Spreng., <i>Lythrum salicaria</i> L., <i>Dianthus chinensis</i> L., <i>Plantago asiatica</i> L., and <i>Viola mandshurica</i> W. Becker
Woody perennials (3)	<i>Lespedeza bicolor</i> Turcz., <i>Lespedeza cuneata</i> (Dum.Cours.) G. Don, and <i>Sorbaria sorbifolia</i> (L.) A. Braun

Note: Values in parentheses are number of species in each category.

100 seeds of each species were placed in a Petri dish lined with filter paper (Whatman no. 1) and moistened with 6 mL-distilled water. The dishes were incubated under fluorescent light for 5 weeks. Germination tests were conducted on three replicates of each species. Species with germination rate <3% were excluded from the study. Seeds of the 17 selected species were sown in pots (22-cm diameter and 30-cm height) filled with fertile agricultural soil. The soil texture was loam, and it was a mixed agricultural soil, a commercial product.

Experimental design

An additive design was used to test the competitive effect of *M. capillaris* on native species (Connolly et al., 2001; Keddy et al., 1994; Snaydon, 1991). In 17 monoculture treatments, 50 viable seeds of a single native species were sown. In 17 competition treatments, each pot contained 50 viable seeds of a single native species plus 50 seeds of *M. capillaris*. The control pot contained only 50 viable seeds of *M. capillaris*. All treatments were sown in March 2021. Seeds were sown by placing them on the top of the soil (not deep), and all seeds were spread with careful attention so that all seeds were equidistantly distributed in each pot. Pots were arranged in a randomized complete block design, with three replicates per treatment (total 108 pots in three blocks). Water was provided by water distribution devices (called water droppers) automatically once per day. Approximately 0.5 L (500 mL) of water per day was provided to each pot. No nutrients

were added to experimental pots because the pots already contained fertile agricultural soil. In the greenhouse, the plants were grown under natural sunlight and outdoor temperature (average = 11°C, minimum = −3.3°C, maximum = 23.2°C, data from the Korean Meteorological Administration) and outdoor humidity (average = 67%, minimum = 59.5%, maximum = 78.5%, data from the Korean Meteorological Administration). For annual plants, seeds were manually collected at the end of the first growing season, then placed in pots for growth in the second year. Annual plants were not replanted.

Data collection

In April, June, and October of 2021 and in April, June, and August of 2022, the number of shoots, plant height, and plant cover of native species in each monoculture, of both species in the competition treatments, and of *M. capillaris* in the control pots were measured to calculate the values of primary response variables (see below). Aboveground biomass was harvested on 7 October 2022

and in early August 2022. Plant cover was visually estimated as the percentage area covered by the plant in each pot. Aboveground shoots of each species were weighed after drying at 80°C for 48 h. Plant height for each species was measured to the nearest 0.5 cm. Additionally, plant cover, plant height, and aboveground biomass of *M. capillaris* were measured to correlate these explanatory variables with the response variables.

Data analysis

The effects of competition and species identity on native plant cover and biomass were tested using ANOVA. A generalized linear mixed model (REML; *F* test) was used to account for the random block effect (Bolker et al., 2009). Normality of residuals and homoscedasticity were evaluated, and the response variables were transformed (log) when necessary. When a significant species identity effect was detected (alpha level of significance = 0.05), Tukey's honestly significant difference (HSD) multiple comparison test was used to compare means. All ANOVA

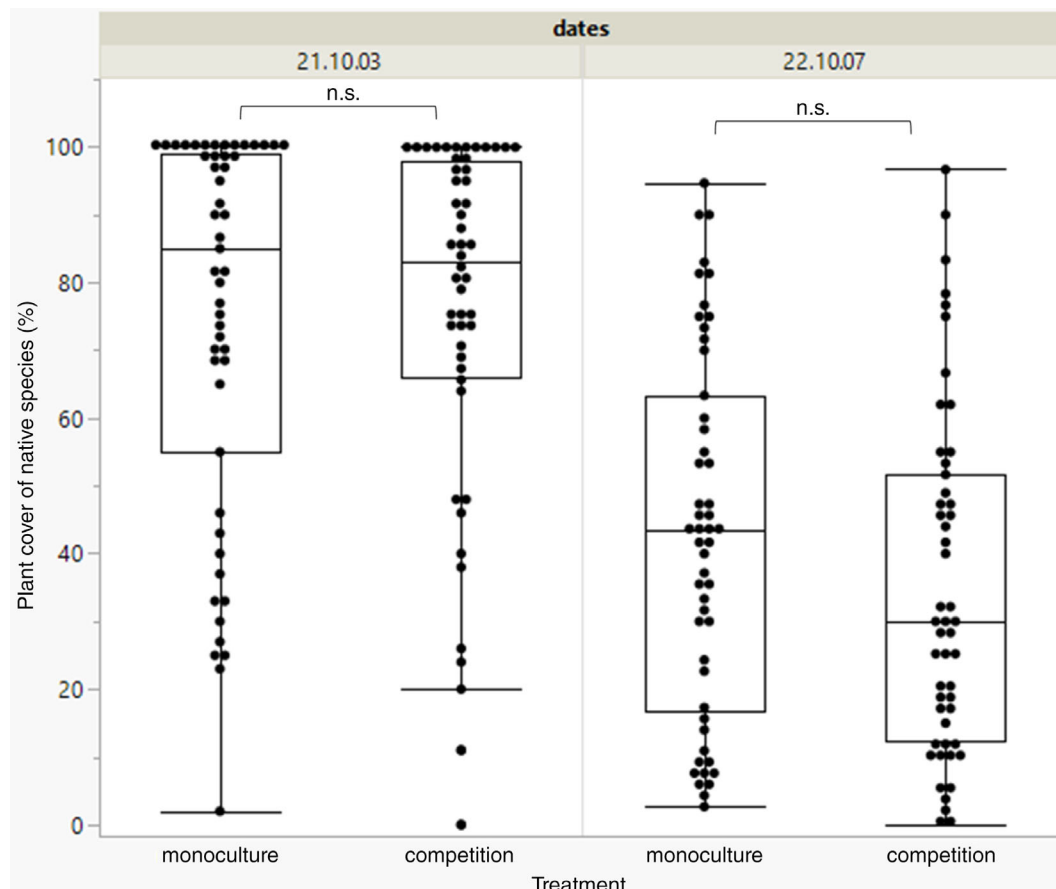


FIGURE 1 The effect of competition with *Muhlenbergia capillaris* on mean percentage cover of 17 native plant species. In the boxplot, the midline indicates the median value; the center's box limits indicate the first quartile (Q1 or 25th percentile), the median of the lower half of the dataset and third quartile (Q3 or 75th percentile), the median of the upper half of the dataset; and whiskers indicate the lowest or highest data point in the dataset excluding any outliers. And lastly, outliers are data point that differs significantly from other observations. n.s., not significant.

tests and correlation analyses were conducted using JMP software (SAS Institute, Cary, NC).

RESULTS

In the first year (measured on 21 October 2021), the mean cover of native plants in competition with *M. capillaris* (mean = 76.03%) was not significantly different from

the value for native plants grown in monoculture (mean = 74.80%; $F_{1,98} = 0.052$; $p = 0.820$; Figure 1). When native plant cover (log-transformed) in monoculture and competitive treatments were compared with respect to species identity, the results were similar (no significant differences) for all species.

In the second year (measured on 7 October 2022), the mean cover of native plants in competition with *M. capillaris* (mean = 34.67%) was again not significantly

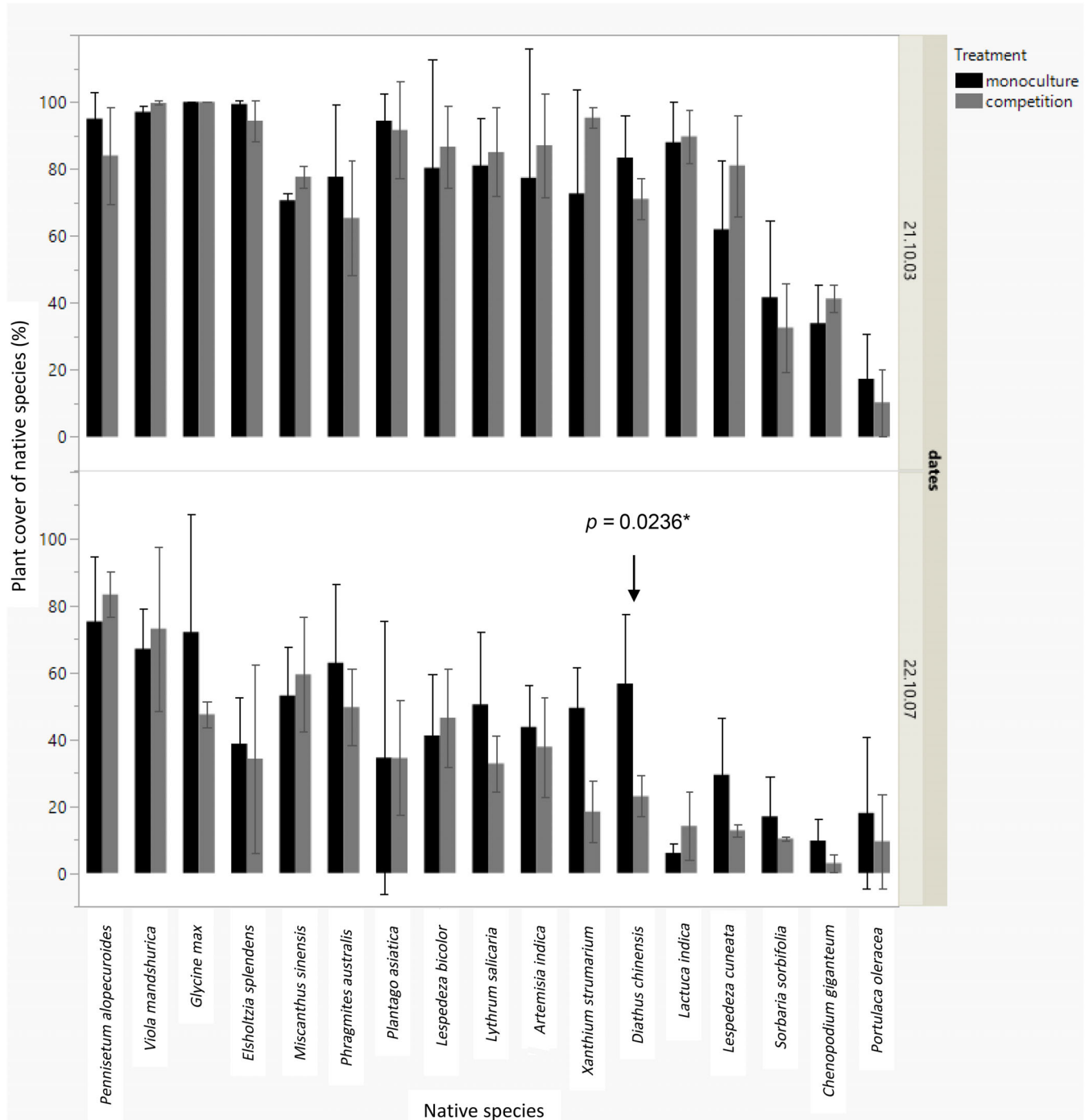


FIGURE 2 The effect of competition with *Muhlenbergia capillaris* on percentage cover of 17 individual native plant species. Error bars show SE. The arrow indicates significant difference between monoculture and competition treatments for that species.

different from the value for native plants grown in monoculture (mean = 42.65%; $F_{1,98} = 2.35$; $p = 0.129$; Figure 1). For individual species, native plant cover

(log-transformed) in monoculture and competitive treatments was significantly different only for *Dianthus chinensis* ($F_{1,2} = 40.872$; $p = 0.024$; Figure 2). A t test

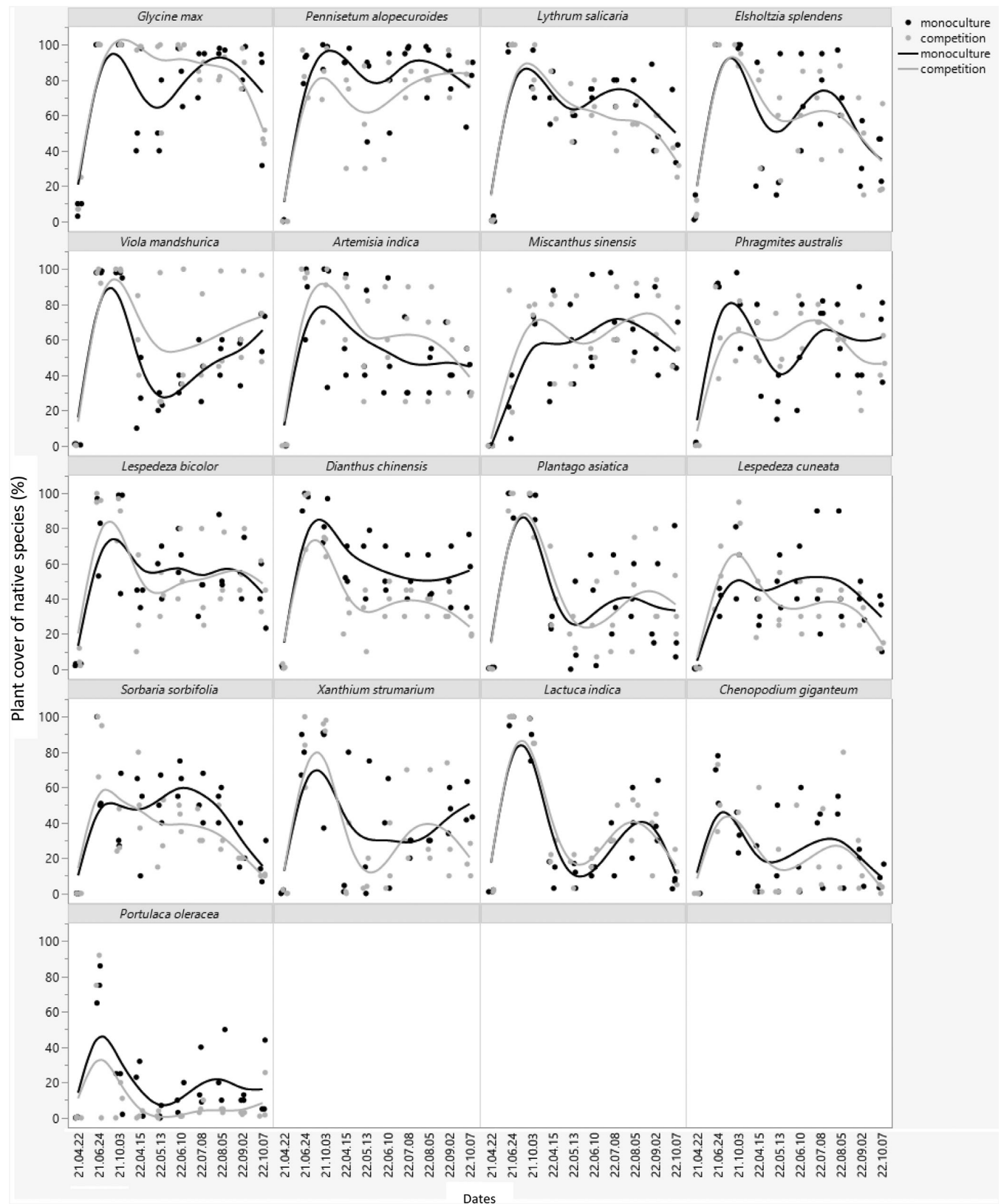


FIGURE 3 Monthly changes in percentage cover of 17 native plant species in monoculture (black line and data points) and in competition with *M. capillaris* (gray line and data points).

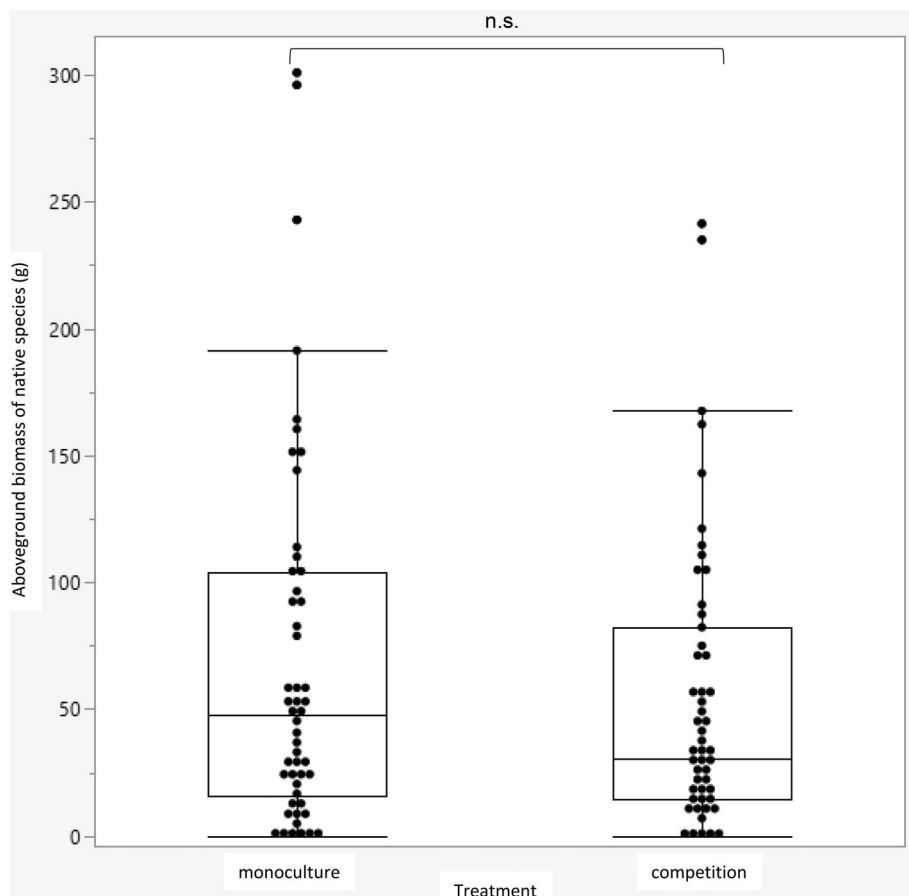


FIGURE 4 The effect of competition with *Muhlenbergia capillaris* on mean aboveground biomass of 17 native plant species. In the boxplot, the midline indicates the median value; the center's box limits indicate the first quartile (Q1 or 25th percentile), the median of the lower half of the dataset and third quartile (Q3 or 75th percentile), the median of the upper half of the dataset; and whiskers indicate the lowest or highest data point in the dataset excluding any outliers. And lastly, outliers are data point that differs significantly from other observations. n.s., not significant.

showed that the cover of *D. chinensis* in competition with *M. capillaris* (least squared mean: 22.50%) was much lower than in monoculture (53.89%). Across the entire experiment, monthly changes of native plant cover in monoculture versus competitive treatments showed a similar pattern with no significant differences (Figure 3).

The mean aboveground biomass of native plants in competition with *M. capillaris* (mean = 55.11 g) was not significantly different from that in monoculture (mean = 69.33 g; $F_{1,98} = 1.17$; $p = 0.280$; Figure 4). When aboveground biomass of native plants (log-transformed) in monoculture and competitive treatments were compared with respect to species identity, significant differences were found only for *D. chinensis* ($F_{1,2} = 37.46$; $P = 0.026$) and *Pennisetum alopecuroides* ($F_{1,2} = 43.63$; $p = 0.022$; Figure 5). A *t* test showed that aboveground biomass of *D. chinensis* in competition with *M. capillaris* (least squared mean: 12.76 g) was significantly lower than in monoculture (34.09 g). The same result was found for

P. alopecuroides (least squared means: 98.79 g in competition and 140.36 g in monoculture).

By contrast, mean cover of *M. capillaris* in competition with native plants was significantly different from that in monoculture ($F_{1,50} = 9.615$; $p = 0.003$; Appendix S1: Figure S1). A *t* test showed that mean cover of *M. capillaris* in competitive treatments (least squared mean: 25.35%) was significantly lower than in monoculture (62.44%).

DISCUSSION

Results clearly showed that plant cover and biomass of native species were not reduced when grown with *M. capillaris* (Figures 1 and 4), suggesting that the non-native *M. capillaris* was not generally a superior competitor. Among the 17 native species, only 2 (*D. chinensis* and *P. alopecuroides*) were significantly affected, but not to the extent of competitive exclusion. This may suggest that *M. capillaris* will not be a serious invasive species in

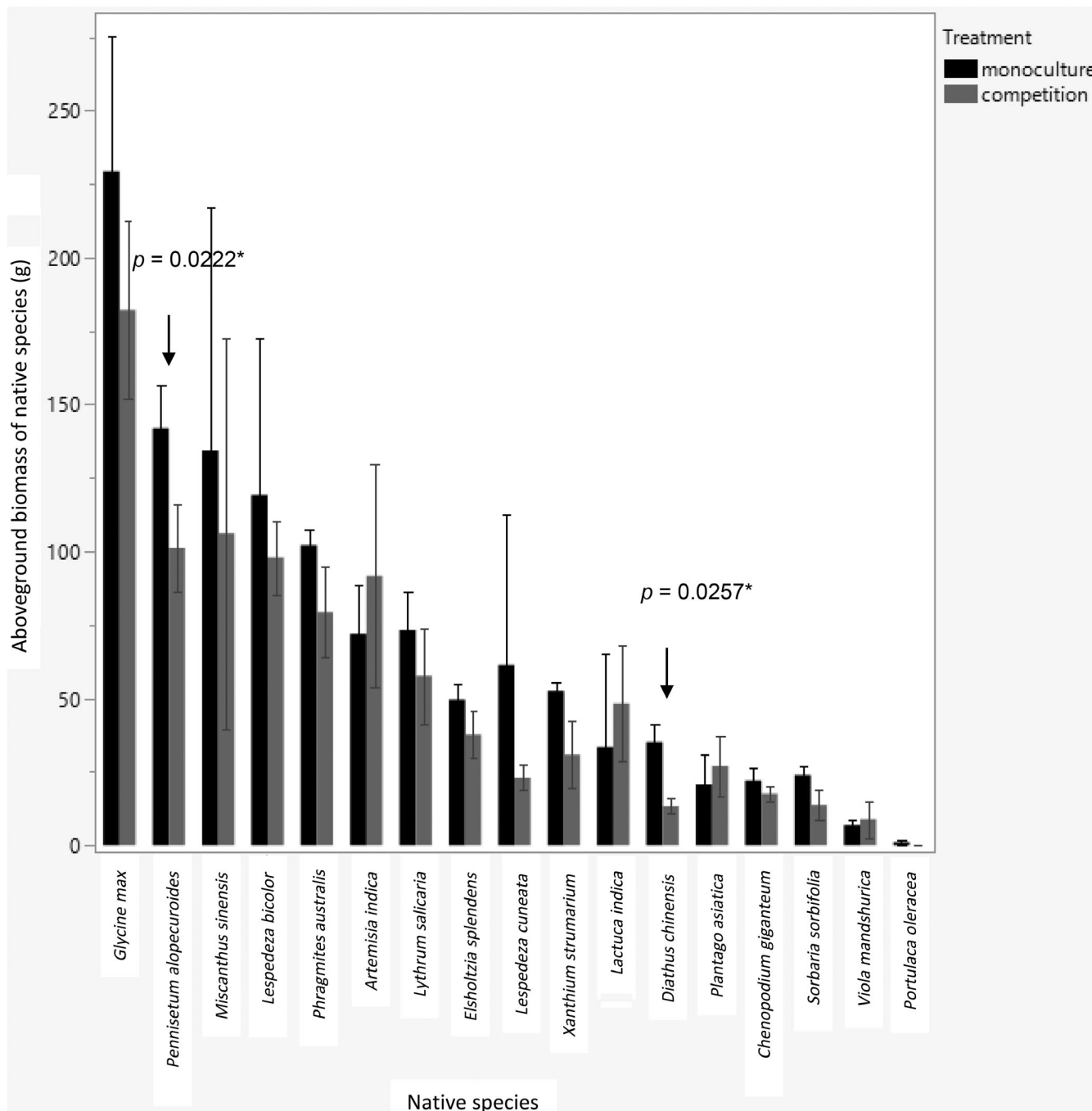


FIGURE 5 The effect of competition with *Muhlenbergia capillaris* on aboveground biomass of 17 individual native plant species. Error bars show SE. The arrows indicate significant difference between monoculture and competition treatments for that species.

South Korea, a conclusion supported by its predicted distribution being limited to a small portion of the Korean peninsula (Park et al., 2020).

Considering the strengths and limitations of the study, the following conclusions can be drawn: (1) Out of 17 native species only 2 (~12%) were weakly and negatively affected in a pairwise competition that will rarely exist in the natural world (Levine et al., 2017). Therefore, *M. capillaris* cannot be considered a harmful invasive

species. (2) Although a pot experiment, this study performed over a period of 2 years, which is sufficient for most invasive species to limit the growth of resident plants (Perkins & Hatfield, 2014), showed that *M. capillaris* did not affect the growth of the native species tested in this study. (3) Given that in diverse natural ecosystems competition for space and resources will likely be higher than created in this study, *M. capillaris* may be competitively excluded in natural settings. The

Ministry of Environment in South Korea has designated *M. capillaris* as an “Ecosystem Hazard Class 2,” and many local governments and landowners are therefore trying to replace it with alternative landscape plants. They are doing so in the absence of information on the effects of *M. capillaris* on native plant communities. Based on the results of this study, it is recommended that current efforts to eradicate *M. capillaris* should cease and be replaced by long-term monitoring of potential expansion from the sites of introduction. Additional data on the morphological traits (seeds, roots, etc.) and dispersal mechanisms of *M. capillaris* will add to our knowledge of its spread and occurrence in natural and disturbed ecosystems. However, given the potential effects of future climate change, the potential expansion of invasive species under different climate scenarios must also be considered (Adhikari et al., 2019).

It should also be noted that: (1) Of the two species whose performance was reduced in competition with *M. capillaris*, *P. alopecuroides* has traits similar to those of its competitor. Trait similarity may confer an advantage to native species in competition with invaders (Funk et al., 2008), but this factor was not apparent here. This indicates the need for further research to test the invasibility of *M. capillaris*. (2) Environmental factors can play a significant role in determining both invasion potential and the resistance of natives to invasion (Byun et al., 2015, 2022). This study was conducted in a homogeneous environment and therefore studies in a range of field conditions are required to determine the relevance of these findings in natural settings. (3) This study used one of the methods suggested in a framework to assess the invasiveness of nonnative or introduced species (Roy et al., 2018; Van Kleunen et al., 2010). This may not be appropriate for determining the negative impacts of *M. capillaris*. Various species introduced to new environments have become noxious weeds impacting agriculture, forests and wetlands, and in some cases simplifying the landscape. This can impose a huge economic burden through the financial cost of management and the negative impact on various ecosystem services (Celesti-Grapow & Ricotta, 2021; Reichard & White, 2001). For example, *Lantana camara* introduced in India, Australia, and South Africa for the purpose of gardening and landscaping has drastically impacted natural ecosystems and resists management despite centuries of effort (Bhagwat et al., 2012; McMahon & Ward, 2021; Shaik et al., 2022).

AUTHOR CONTRIBUTIONS

Chaeho Byun conceived the study, designed the experiments, analyzed the data, and wrote the manuscript.

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CONFLICT OF INTEREST STATEMENT

The author declares no conflicts of interest.

DATA AVAILABILITY STATEMENT

Data (Byun, 2023) are available from Figshare: <https://doi.org/10.6084/m9.figshare.22583947.v2>.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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