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Does Atmospheric Nitrogen Deposition Confer a Competitive Advantage to Invasive *Bidens pilosa* L. over Native *Pterocypsela laciniata* (Houtt.) Shih?

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Abstract: One of the key reasons for the success of invasive plants is the functional differences between invasive plants and native plants. However, atmospheric nitrogen deposition may disrupt the level of available nitrogen in soil and the functional differences between invasive plants and native plants, which may alter the colonization of invasive plants. Thus, there is a pressing necessity to examine the effects of atmospheric nitrogen deposition containing different nitrogen components on the functional differences between invasive plants and native plants. However, the progress made thus far in this field is not sufficiently detailed. This study aimed to elucidate the effects of artificially simulated nitrogen deposition containing different nitrogen components (i.e., nitrate, ammonium, urea, and mixed nitrogen) on the functional differences between the Asteraceae invasive plant *Bidens pilosa* L. and the Asteraceae native plant *Pterocypsela laciniata* (Houtt.) Shih. The study was conducted over a four-month period using a pot-competitive co-culture experiment. The growth performance of *P. laciniata*, in particular with regard to the sunlight capture capacity (55.12% lower), plant supporting capacity (45.92% lower), leaf photosynthetic area (51.24% lower), and plant growth competitiveness (79.92% lower), may be significantly inhibited under co-cultivation condition in comparison to monoculture condition. *Bidens pilosa* exhibited a more pronounced competitive advantage over *P. laciniata*, particularly in terms of the sunlight capture capacity (129.43% higher), leaf photosynthetic capacity (40.06% higher), and enzymatic defense capacity under stress to oxidative stress (956.44% higher). The application of artificially simulated nitrogen deposition was found to facilitate the growth performance of monocultural *P. laciniata*, particularly in terms of the sunlight capture capacity and leaf photosynthetic area. *Bidens pilosa* exhibited a more pronounced competitive advantage (the average value of the relative dominance index of *B. pilosa* is ≈ 0.8995) than *P. laciniata* under artificially simulated nitrogen deposition containing different nitrogen components, especially when treated with ammonium (the relative dominance index of *B. pilosa* is ≈ 0.9363) and mixed nitrogen (the relative dominance index of *B. pilosa* is ≈ 0.9328). Consequently, atmospheric nitrogen deposition, especially the increased relative proportion of ammonium in atmospheric nitrogen deposition, may facilitate the colonization of *B. pilosa* via a stronger competitive advantage.

Keywords: ammonium; co-cultivation condition; functional difference; growth performance; relative dominance

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1. Introduction

Invasive plants (IPs) can have a profound impact on environmental health and ecological security. In particular, IPs can affect the structure and ecological function of native ecosystems, which can result in the loss of native biodiversity [1–4]. At present, there are in excess of 500 IPs distributed throughout China [5,6]. In particular, the Asteraceae family has the highest species number of IPs at the family classification level, with a total of 92 IPs in the family Asteraceae [5,6]. Thus, the investigation of the mechanisms underlying the success of IPs, particularly those belonging to the Asteraceae family, represents a pivotal area of research within the field of invasion ecology in recent years [7–9].

One of the key reasons for the success of IPs is the functional differences between IPs and native plants. In particular, both IPs and native plants are subject to similar, if not identical, selection pressures, exerted by the environment [10–13]. More importantly, IPs generally exhibit higher values for the key functional traits, including plant height, leaf area, photosynthetic capacity, nutrient use efficiency, and environmental tolerance, etc. Consequently, they exhibit higher growth performance compared to native plants, even under stressful environments [14–17]. It is therefore essential to illuminate the functional differences and differences in growth performance-related functional traits between IPs and native plants to identify the intrinsic mechanisms that determine whether an IP is successfully invaded.

In general, nitrogen (N) is the main nutrient limiting plant growth in several terrestrial ecosystems [18–21]. Therefore, the capacity of IPs to obtain N is a pivotal element in determining their success in colonizing diverse habitats. More importantly, it is evident that IPs exhibit a greater capacity for N acquisition compared to native plants, due to their high availability and utilization of N [22–25]. In addition, the invasiveness and invasion intensity of numerous IPs are significantly related to the level of available N in soil [26–29]. Nevertheless, atmospheric N deposition may significantly disrupt the level of available N in soil and the interactions between IPs and native plants, which may influence the colonization of IPs.

In recent years, there has been a notable increase in atmospheric N deposition, which is largely attributed to the release of N-containing compositions into the atmosphere as a consequence of the excessive combustion of fossil fuels, unreasonable and/or unsuitable production and consumption of N-containing fertilizers, and the fast expansion of animal husbandry and cultivation [30–33]. Presently, East Asia (predominantly China) has one of the three maximum rates of atmospheric N deposition globally [31,34–36]. In addition, other parts of the globe are also experiencing more serious atmospheric N deposition problems, such as Europe and the United States [33,37–39]. Nevertheless, it has been demonstrated that atmospheric N deposition may promote the invasiveness of several IPs, which in turn leads to the acceleration of the colonization of IPs by increasing the level of available N in soil [40–43]. However, atmospheric N deposition encompasses a multitude of different N components, including nitrate (NO_3-N), ammonium (NH_4-N), urea ($CO(NH_2)_2$-N), etc., and that the relative proportions of these N components in atmospheric N deposition may also be subject to change contingent on the alterations in energy policy and the composition of energy sources employed [31,34–36]. Nevertheless, atmospheric N deposition containing different N components can result in alterations in the level of available N in soil and the interactions between IPs and native plants. Such variations may result in differences in the functional differences between IPs and native plants. This could have a significant impact on the colonization of IPs. Therefore, there is a compelling rationale for investigating the effects of atmospheric N deposition containing different N components on the functional differences between IPs and native plants, with the aim of elucidating the mechanisms that facilitate the success of IPs in the context of atmospheric N deposition, particularly in the context of different N components. Nevertheless, the current state of knowledge in this field is not sufficiently detailed.

This study aimed to elucidate the effects of artificially simulated N deposition containing different N components (including nitrate (NO_3-N), ammonium (NH_4-N), urea

($CO(NH_2)_2$-N), and mixed N with NO_3-N:NH_4-N:$CO(NH_2)_2$-N = 1:1:1) on the functional differences between the Asteraceae IPs *Bidens pilosa* L. and the Asteraceae native plant *Pterocypsela laciniata* (Houtt.) Shih. The study was conducted over a four-month period using a pot-competitive co-culture experiment. *Bidens pilosa* is a member of the Asteraceae family, and the species number of IPs belonging to this family that have been introduced to China is higher than that of any other family at the family level [5,6]. *Bidens pilosa* is native to tropical America and was introduced to China in ~1857 with imported crops and vegetables. In particular, the species number of IPs sourced from America is higher than that sourced from other countries and/or districts in China [5,6]. However, *B. pilosa* has been identified as a significant threat to ecosystem structure and function, particularly in terms of the loss of native biodiversity in China, and *B. pilosa* has been classified as a harmful IP in China [2,44–46]. The two Asteraceae plants occupy similar habitats, including agroecosystems, wasteland, and areas adjacent to the main road in China. Additionally, the two Asteraceae plants also share similar lifestyles, with erect herbs being a common feature. Furthermore, they exhibit comparable plant heights, reaching up to ≈2–3 m. More importantly, the two Asteraceae plants frequently co-occur in the same habitats, such as agroecosystems, wasteland, and areas adjacent to the main road, etc. Furthermore, the distributions of the two Asteraceae plants in China are among the areas most affected by atmospheric N deposition [31,34–36].

The following questions were proposed for this study: (1) Does *B. pilosa* exhibit higher values of the key functional traits (e.g., plant height, leaf area, and leaf nitrogen and chlorophyll contents) compared to *P. laciniata*? (2) Does artificially simulated N deposition confer a competitive advantage to *B. pilosa* over *P. laciniata*? (3) Which component of artificially simulated N deposition exerts the greatest influence on the competitive advantage of *B. pilosa*?

2. Materials and Methods

2.1. Experimental Design

Bidens pilosa (Figure S1) was designated as the target IP. *Pterocypsela laciniata* (Figure S2) was proposed as the native species. Seeds of both plants were collected in October 2022 from Zhenjiang, Jiangsu, China (32.15–32.16° N; 119.52–119.53° E). The selected ecosystems were classified as wastelands. *Bidens pilosa* was the only invasive plant species in the sampled communities. It is likely that the selected *B. pilosa* individuals were naturally dispersed in the sampled communities. The native plant species in the sampled communities are dominated by herbaceous plants, such as *Setaria viridis* (L.) P. Beauv., *Echinochloa crus-galli* (L.) P. Beauv., *Arthraxon hispidus* (Trin.) Makino, and *Artemisia argyi* H. Lév. and Vaniot. The geographical location of the sampling area is provided in Figure S3. Zhenjiang has a humid subtropical monsoon climate, and in 2022 the average annual temperature in Zhenjiang was ~17.1 °C, and an average monthly temperature reached a maximum of ~28.1 °C in July and a minimum of ~3.7 °C in January [47]. In 2022, the annual sunshine hours in Zhenjiang were ~1909.0 h, and the monthly average sunshine hours reached a maximum value of ~208.2 h in December, and a minimum value of ~125.9 h in August [47]. The annual precipitation in Zhenjiang in 2022 was ~1164.1 mm, and the average monthly precipitation reached a maximum value of ~432.1 mm in July, and a minimum value of ~2.7 mm in December [47].

A pot competitive co-culture experiment was conducted to examine the growth of *B. pilosa* and *P. laciniata* (Figure S4). Pasture yellow soil (manufacturer: Shenzhibei Sci. & Technol. Co., Ltd., Baishan, China; pH value: ~6.3; soil electrical conductivity: ≤3 ms/cm; organic content: ≥30%; ~3 kg/planting basin) was used as culture substrate. The reason for using pasture yellow soil as a culture substrate was to minimize the potential for previous introduction of IPs, as well as to reduce the risk of contamination from atmospheric N deposition in natural soils. The seeds of both plants were placed in garden pots (top diameter 25 cm; height 16.5 cm). Six uniformly sized, vigorous of *B. pilosa* and/or *P. laciniata* seedlings were cultivated in each garden pot. The following treatments were employed:

(1) six *B. pilosa* seedlings were planted in each garden pot, representing a monoculture of *B. pilosa*; (2) three *B. pilosa* seedlings and three *P. laciniata* seedlings were planted in each garden pot, representing a co-culture of *B. pilosa* and *P. laciniata*; (3) six *P. laciniata* seedlings were planted in each garden pot, representing a monoculture of *P. laciniata*. All garden pots were treated with artificially simulated N deposition, specifically (1) nitrate (potassium nitrate (KNO_3, AR, ≥99%; Aladdin®, Shanghai, China); inorganic nitrogen); (2) ammonium (ammonium chloride (NH_4Cl, GR, ≥99.8%; Sinopharm Chemical Reagent Co., Ltd., Shanghai, China); inorganic nitrogen); (3) urea ($CO(NH_2)_2$, BC, ≥99.5%; Sangon Biotech Co., Ltd., Shanghai, China; organic nitrogen); (4) mixed N (nitrate:ammonium:urea = 1:1:1), at 5 g N m^{-2} yr^{-1}. Sterile distilled water was used as the control (0 g N L^{-1}). The content of artificially simulated N deposition, which contained different N components, replicated the actual content of natural atmospheric N deposition (i.e., 5 g N m^{-2} yr^{-1}) in the southern Jiangsu, China [34,35,48,49]. The proportions of the three monomers in the N mixture were designed to simulate the actual proportions of natural atmospheric N deposition (i.e., equal mixing) in the southern Jiangsu, China [50–52]. The present study tested a range of planting type combinations (i.e., monocultural *B. pilosa*, co-cultivated *B. pilosa* and *P. laciniata*, and monocultural *P. laciniata*) and N component combinations (i.e., nitrate, ammonium, urea, and mixed N). Three replicates were arranged for each treatment. Seedlings of both plants were cultivated in the greenhouse at Jiangsu University, Zhenjiang, Jiangsu, China (32.2061° N, 119.5128° E) under natural light from April to July 2023 for ~4 months. The design of this experiment is shown in Figure 1.

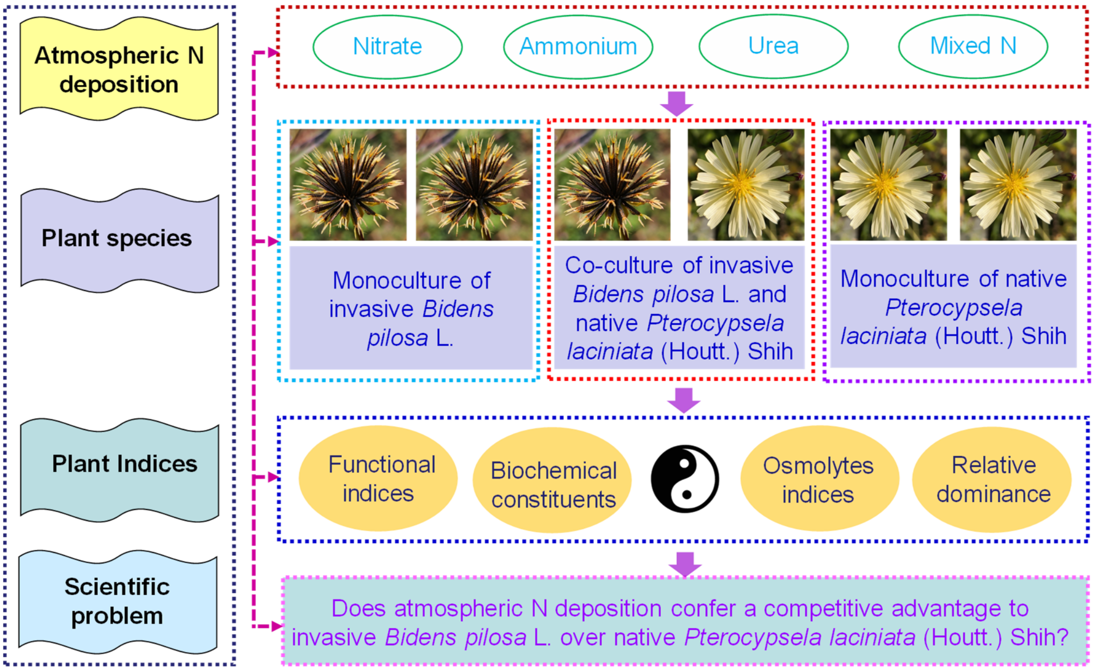


Figure 1. The chart of the experimental design in this study.

Following ~4 months of pot competitive co-culture experimentation, all individuals of *B. pilosa* and *P. laciniata* were collected to determine their functional indices, biochemical constituents, and osmolytes indices of *B. pilosa* and *P. laciniata*, as well as the relative dominance index of *B. pilosa*.

2.2. Determination of Plant Indices

The functional traits closely related to the growth performance of *B. pilosa* and *P. laciniata*, including plant height, ground diameter, leaf dimensions, green leaf area, specific leaf area, leaf chlorophyll and N contents, and biomass, were determined. The biomass stability index of both plants and the relative dominance index of *B. pilosa* were also quantified.

Similarly, biochemical constituents, and osmolytes indices of both plants were determined. The ecological significance, measuring method, and the corresponding references of the analyzed indices in this study are presented in Table S1.

2.3. Statistical Analysis

Shapiro–Wilk's test and Bartlett's test were employed to determine the extent of departure from the normality and the homogeneity of the examined variances, respectively. The statistical analysis of the differences in the values of the functional indices, biochemical constituents, and osmolytes indices of *B. pilosa* and *P. laciniata*, as well as the relative dominance index of *B. pilosa* among different treatments was conducted using the one-way analysis of variance (ANOVA) with the Duncan's test. Two-way ANOVA was employed to evaluate the effects of plant species and N component on the functional indices, biochemical constituents, and osmolytes indices of *B. pilosa* and *P. laciniata*. The effect size of each factor was also evaluated using Partial Eta Squared (η^2), which were calculated to be used in a two-way ANOVA. $p \leq 0.05$ was considered to represent a statistically significant difference. Statistical analyses were conducted using IBM SPSS Statistics 26.0 (IBM, Inc., Armonk, NY, USA).

3. Results and Discussion

Plant height, ground diameter, leaf width, green leaf area, and biomass of co-cultivated *P. laciniata* were significantly lower than those of monocultural *P. laciniata* ($p < 0.05$; Figures 2–4). Thus, the sunlight capture capacity, plant supporting capacity, leaf photosynthetic area, and plant growth competitiveness of co-cultivated *P. laciniata* were found to be significantly lower than those of monocultural *P. laciniata*. Hence, the growth performance of *P. laciniata* may be significantly reduced under co-cultivation conditions compared to monoculture condition. The diminished growth performance of *P. laciniata* under co-cultivation conditions may be attributed to the decreased availability of nutrients (especially N) resulting from the intensified interspecific competition under co-cultivation conditions. Our previous studies have also provided evidence to support this conclusion [53–56]. More importantly, no significant differences were detected in the growth performance of *B. pilosa* between the monoculture and co-cultivation conditions in the majority of cases ($p > 0.05$; Figures 2–5). Accordingly, the competitive advantage of *B. pilosa* is not affected by cultivation type. Consequently, *B. pilosa* exhibited a more pronounced competitive advantage compared to *P. laciniata*, especially under co-cultivation conditions.

The functional differences between IPs and native plants may be of critical importance in determining the success of IPs. More importantly, the results demonstrated that IPs exhibited a more pronounced competitive advantage over native plants, which were recruited by the higher values of key functional traits, such as plant height, leaf area, photosynthetic capacity, nutrient use efficiency, and environmental tolerance, etc. Consequently, Ips demonstrated superior growth performance than native plants, even under stressful environments [11,14–16]. Similarly, the plant height, leaf chlorophyll and N contents, and plant peroxidase activity of *B. pilosa* were significantly higher than those of *P. laciniata* under both monoculture and co-cultivation conditions ($p < 0.05$; Figures 2, 3 and 6). More importantly, plant species significantly affected all functional indices (except ground diameter) ($p < 0.00001$; Table S2). Thus, *B. pilosa* exhibited a more pronounced competitive advantage in comparison to *P. laciniata*. The pronounced competitive advantage of *B. pilosa* is likely attributable to its stronger sunlight capture capacity, leaf photosynthetic capacity, and enzymatic defense capacity under stress to oxidative stress compared to *P. laciniata*. However, leaf length of *B. pilosa* was found to be significantly shorter than that of *P. laciniata* under both monoculture and co-cultivation conditions ($p < 0.05$; Figure 3). Thus, the leaf photosynthetic area of *B. pilosa* was found to be significantly smaller than that of *P. laciniata* under both monoculture and co-cultivation conditions. Accordingly, the leaf photosynthetic area does not appear to be a determining factor in the strong competitive advantage exhibited by *B. pilosa*. In other words, *B. pilosa* can obtain a strong competitive advantage mainly by means of partial key functional traits, e.g., stronger sunlight capture capacity, leaf photosynthetic capacity, and enzymatic defense capacity under stress to oxidative stress. The significantly functional differences between *B. pilosa* and *P. laciniata* permit *B. pilosa* to gain a stronger competitive advantage and to occupy more ecological niches in the habitats, which support the niche differentiation hypothesis (i.e., invasive and native species tend to exhibit functional divergence, resulting in invasive species exhibiting distinct functional traits compared to native species, thereby enabling the former to successfully invade new habitats via the higher growth competitiveness) [57–60] and the Darwin's naturalization hypothesis (i.e., invasive species that are phylogenetically unrelated to native species should be more successful, as they can exploit the unoccupied ecological niches in the invaded communities) [61–64]. Accordingly, the "Master-of-some" strategy (i.e., invasive species are more competitive in favorable habitat, such as the increased resource availability), in contrast to the "Jack-of-all" strategy (i.e., invasive species are more competitive in stressful habitats, such as the decreased resource availability) or "Jack and master" strategy (i.e., invasive species are more competitive in both unfavorable and favorable habitats) [65–67], serves to enhance the competitive advantage of *B. pilosa*, especially under atmospheric nitrogen deposition.

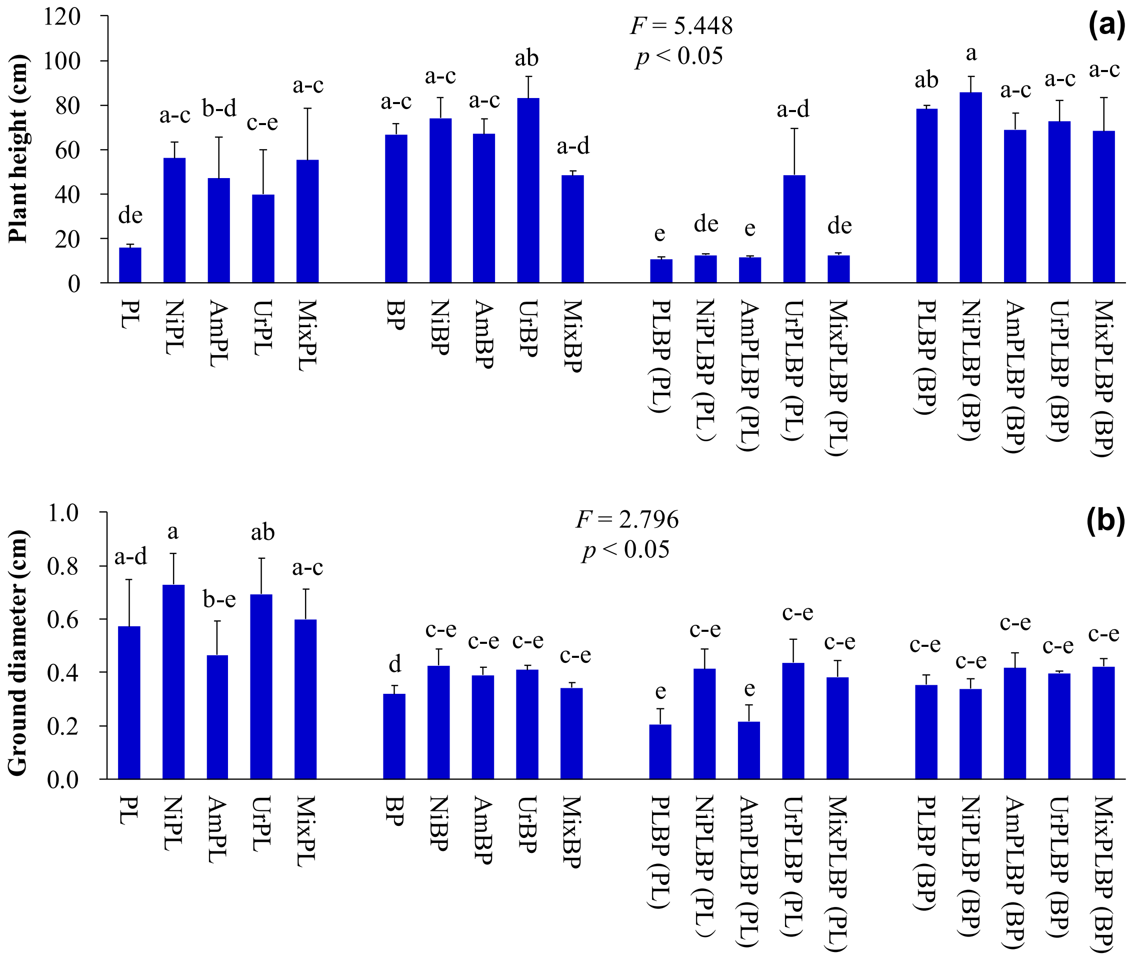
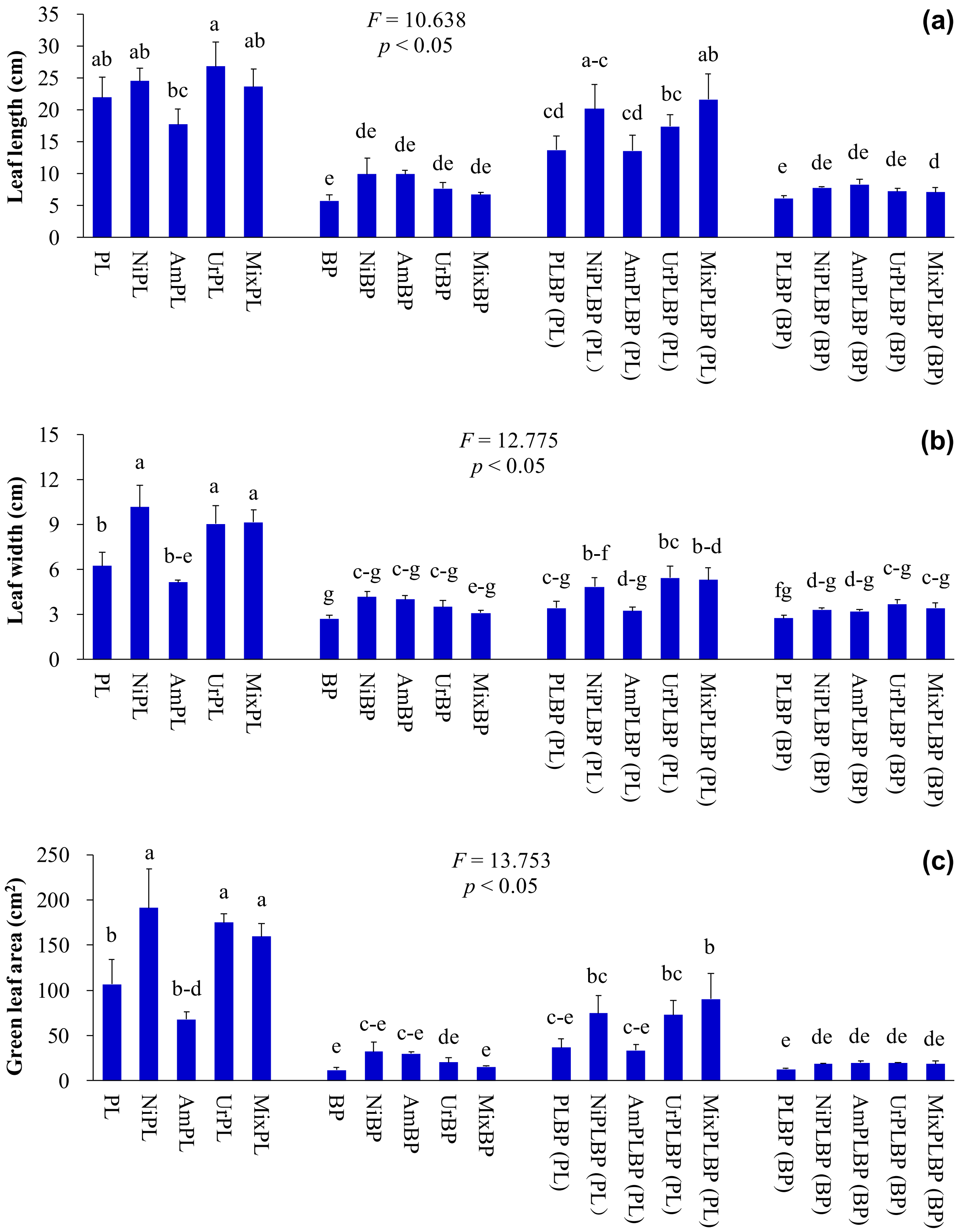


Figure 2. Plant height and ground diameter of *B. pilosa* and *P. laciniata* under monoculture and co-cultivation conditions, respectively ((**a**), plant height; (**b**), ground diameter). Bars (mean and standard error, $n = 3$) with different lowercase letters representing statistically significant differences ($p \leq 0.05$). Abbreviations: PL, monocultural *P. laciniata*; NiPL, monocultural *P. laciniata* treated with nitrate; AmPL, monocultural *P. laciniata* treated with ammonium; UrPL, monocultural *P. laciniata* treated with urea; MixPL, monocultural *P. laciniata* treated with mixed N; BP, monocultural *B. pilosa*; NiBP, monocultural *B. pilosa* treated with nitrate; AmBP, monocultural *B. pilosa* treated with ammonium;

UrBP, monocultural *B. pilosa* treated with urea; MixBP, monocultural *B. pilosa* treated with mixed N; PLBP(PL), co-cultivated *P. laciniata*; NiPLBP(PL), co-cultivated *P. laciniata* treated with nitrate; AmPLBP(PL), co-cultivated *P. laciniata* treated with ammonium; UrPLBP(PL), co-cultivated *P. laciniata* treated with urea; MixPLBP(PL), co-cultivated *P. laciniata* treated with mixed N; PLBP(BP), co-cultivated *B. pilosa*; NiPLBP(BP), co-cultivated *B. pilosa* treated with nitrate; AmPLBP(BP), co-cultivated *B. pilosa* treated with ammonium; UrPLBP(BP), co-cultivated *B. pilosa* treated with urea; Mix AmPLBP(BP), co-cultivated *B. pilosa* treated with mixed N.



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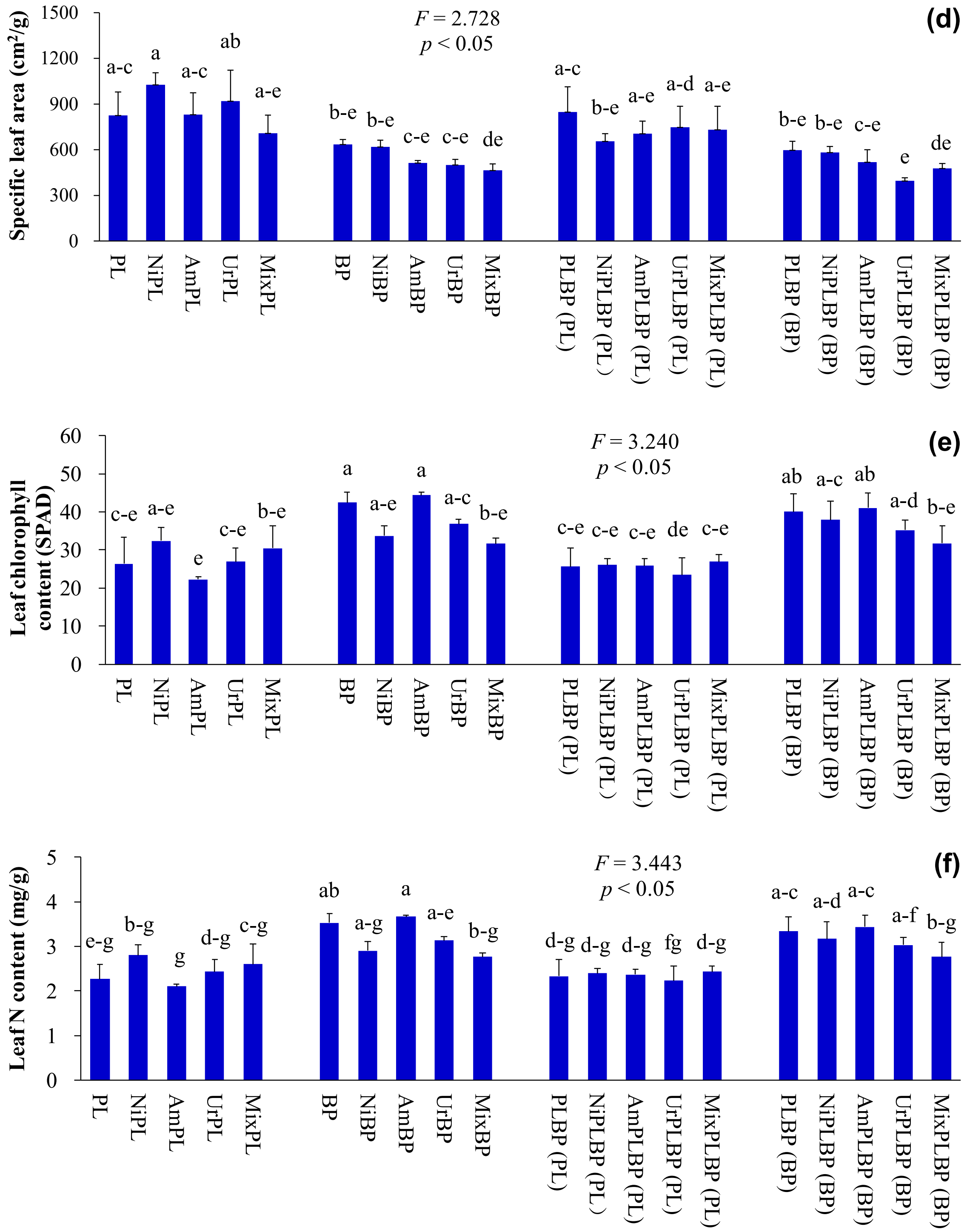

Figure 3. Leaf functional traits of *B. pilosa* and *P. laciniata* under monoculture and co-cultivation conditions, respectively ((**a**), leaf length; (**b**), leaf width; (**c**), green leaf area, (**d**), specific leaf area, (**e**), leaf chlorophyll content; (**f**), leaf N content). Bars (mean and standard error, n = 3) with different lowercase letters representing statistically significant differences ($p \leq 0.05$). Abbreviations have the same meanings as described in Figure 2.

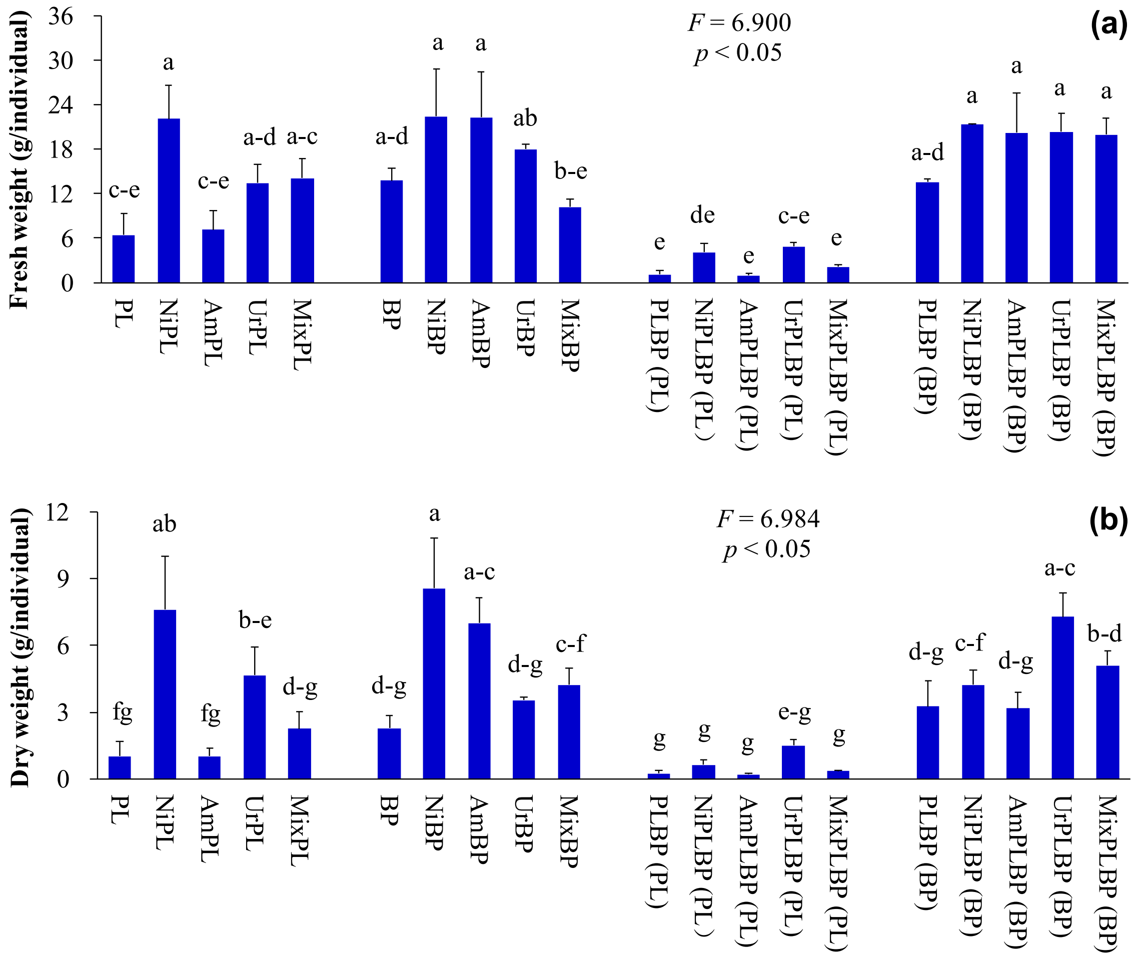

Figure 4. Biomass of *B. pilosa* and *P. laciniata* under monoculture and co-cultivation conditions, respectively ((**a**), fresh weight; (**b**), dry weight). Bars (mean and standard error, $n = 3$) with different lowercase letters representing statistically significant differences ($p \leq 0.05$). Abbreviations have the same meanings as described in Figure 2.

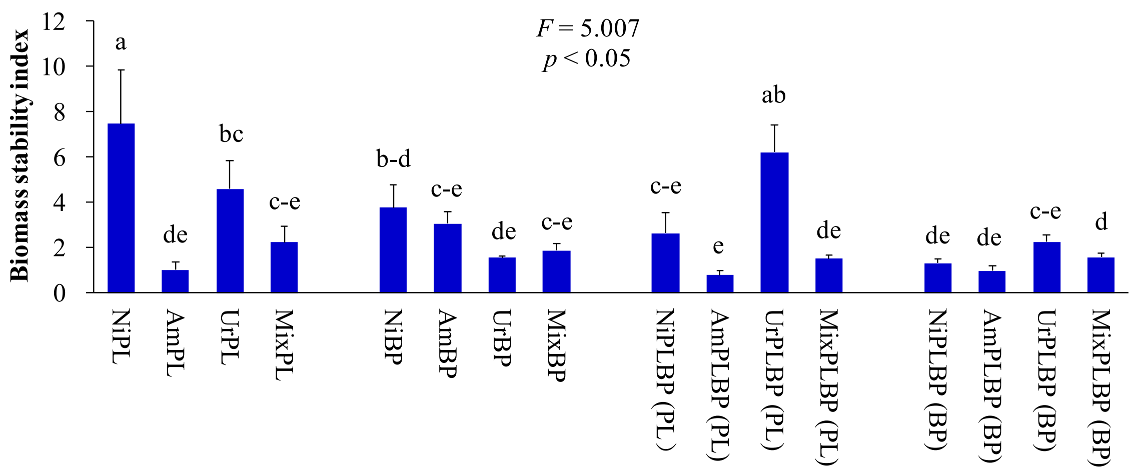

Figure 5. The biomass stability index of *B. pilosa* and *P. laciniata* under monoculture and co-cultivation conditions, respectively. Bars (mean and standard error, $n = 3$) with different lowercase letters representing statistically significant differences ($p \leq 0.05$). Abbreviations have the same meanings as described in Figure 2.

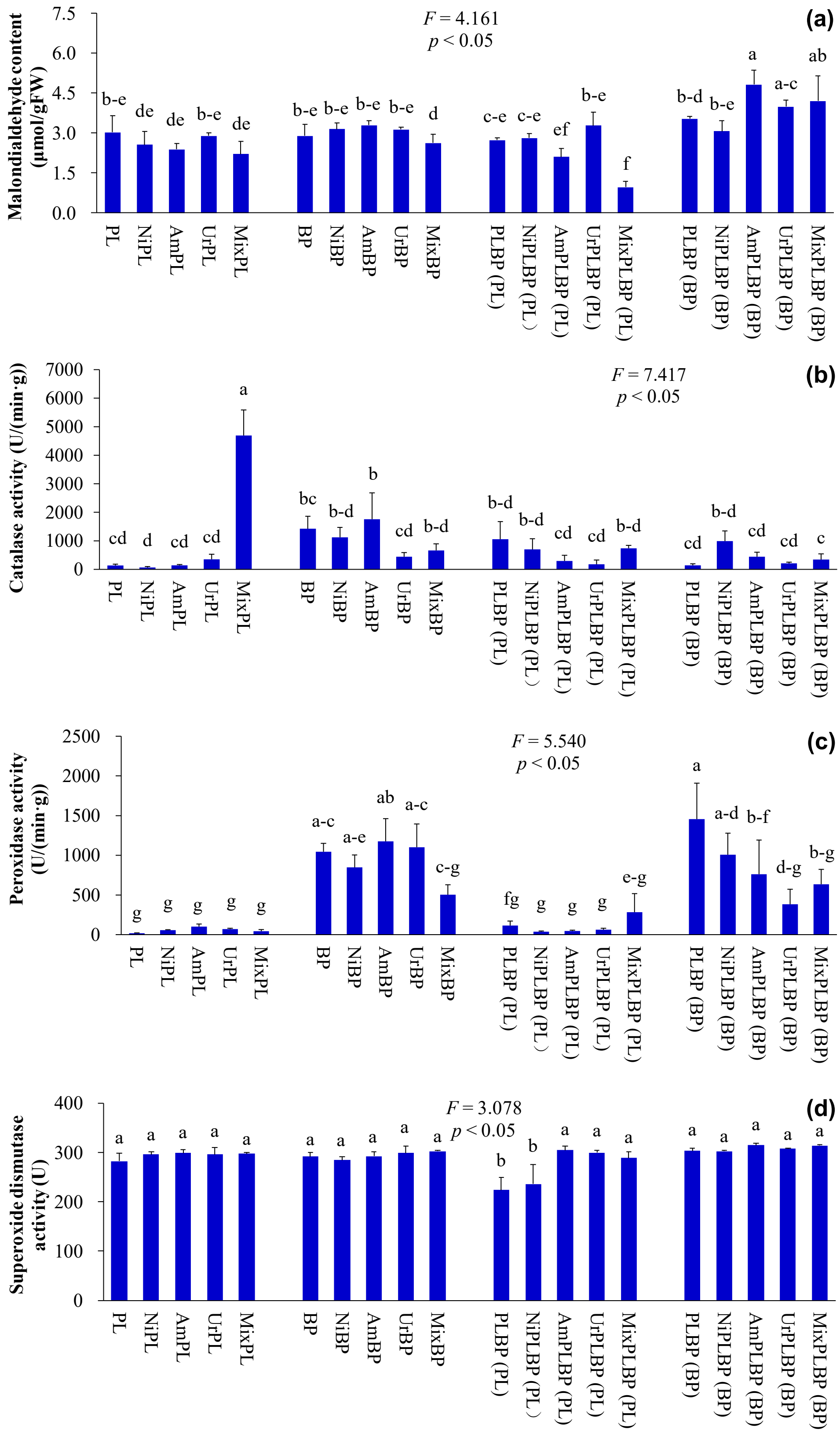

Figure 6. Biochemical constituents and osmolytes indices of *B. pilosa* and *P. laciniata* under monoculture and co-cultivation conditions, respectively ((**a**), malondialdehyde content; (**b**), catalase activity; (**c**), peroxidase activity; (**d**), superoxide dismutase activity). Bars (mean and standard error, $n = 3$) with different lowercase letters represent statistically significant differences ($p \leq 0.05$). Abbreviations have the same meanings as described in Figure 2.

As one of the essential nutrients required by plants, the application of exogenous N generally results in the enhanced growth performance of plants, attributed to the increased level of available N in soil. This is evidenced by numerous studies [68–71]. Similarly, the application of artificially simulated N deposition led to a significant increase in plant height, leaf width, and green leaf area of monocultural *P. laciniata* in the majority of cases ($p < 0.05$; Figures 2 and 3). Thus, the application of artificially simulated N deposition may be beneficial to the growth performance of monocultural *P. laciniata*, particularly in terms of the sunlight capture capacity and leaf photosynthetic area.

It can be generally observed that N acquisition and utilization capacity is a crucial factor in the success of IPs [22–25]. Hence, the application of exogenous N can facilitate the invasiveness of IPs. In this study, the values of the relative dominance index of *B. pilosa* (average value is ≈0.8995) was found to be obviously greater than 0.5 when exposed to artificially simulated N deposition containing different N components, especially when exposed to ammonium (the relative dominance index of *B. pilosa* is ≈0.9363) and mixed nitrogen (the relative dominance index of *B. pilosa* is ≈0.9328) (Figure 7). Consequently, *B. pilosa* demonstrated a more pronounced competitive advantage than *P. laciniata* under the application of artificially simulated N deposition containing different N components, especially when treated with ammonium and mixed N. Accordingly, artificially simulated N deposition, regardless of N component, may be conducive to the success of *P. laciniata*, especially under the deposition of ammonium and mixed N. This finding may be attributed to the fact that *B. pilosa* exhibits a proclivity for ammonium uptake and utilization. In particular, previous studies have demonstrated that other IPs also displays a preference for ammonium uptake and utilization over other N components [42,72–74]. It is noteworthy that the relative proportion of ammonium in atmospheric N deposition is increasing in certain countries and regions, including China [75–77] and the United States of America [78–80]. Accordingly, the augmented relative proportion of ammonium in atmospheric N deposition may further facilitate the colonization of *B. pilosa* via a more pronounced competitive advantage.

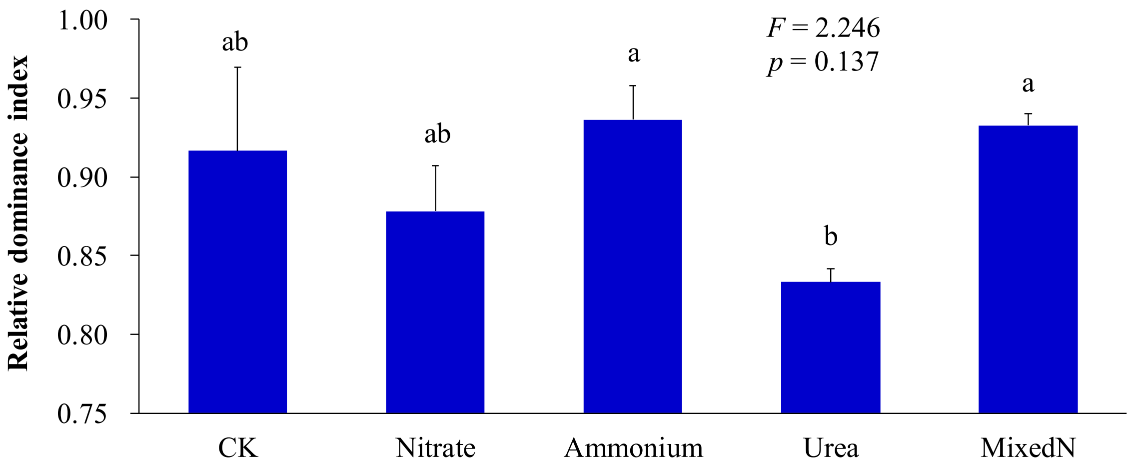

Figure 7. The relative dominance index of *B. pilosa* under co-cultivation condition. Bars (mean and standard error, $n = 3$) with different lowercase letters represent statistically significant differences ($p \leq 0.05$). Abbreviations have the same meanings as described in Figure 2.

In essence, there is a pressing need to impede or even halt the colonization of *B. pilosa*, especially under co-cultivation conditions and when exposed to atmospheric N deposition, particularly when there is an increase in the relative proportion of ammonium in atmospheric N deposition. The findings of this study also provide a substantial practical basis for the environmental management of IPs, including effective early warning prevention and control of IPs, especially when exposed to atmospheric N deposition. In particular, it is of great importance to reduce the level of atmospheric N deposition, in particular the proportion of ammonium, via the alterations in energy policy and the composition of energy sources employed. This is to minimize the competitive advantage of *B. pilosa* under atmospheric N deposition, especially with an increase in the relative proportion of ammonium in atmospheric N deposition.

4. Conclusions

In conclusion, this study aims to elucidate the functional differences between *B. pilosa* and *P. laciniata* in the context of atmospheric N deposition containing different N components. The principal findings are as follows: (1) The sunlight capture capacity, plant supporting capacity, leaf photosynthetic area, and plant growth competitiveness of co-cultivated *P. laciniata* were found to be significantly lower than those of monocultural *P. laciniata*. (2) The sunlight capture capacity, leaf photosynthetic capacity, and enzymatic defense capacity under stress to oxidative stress of *B. pilosa* were meaningfully greater than those of *P. laciniata* under both monoculture and co-cultivation conditions. (3) The results of the artificially simulated N deposition demonstrated a significant increase in plant height, leaf width, and green leaf area of monocultural *P. laciniata* in the majority of cases. (4) The values of the relative dominance index of *B. pilosa* were found to be significantly greater than 0.5 in response to artificially simulated N deposition containing different N components, especially when exposed to ammonium and mixed N. In summary, atmospheric N deposition, especially the increased relative proportion of ammonium in atmospheric N deposition, may facilitate the colonization of *B. pilosa* via a stronger competitive advantage.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/atmos15070825/s1, Table S1 [81–96]: The ecological significances, determination methods, and the corresponding references for the determined indices; Table S2: Two-way ANOVA on the effects of plant species and nitrogen component on the functional indices, biochemical constituents, and osmolytes indices of *B. pilosa* and *P. laciniata*. *p* values equal to or less than 0.05 are shown in bold; Figure S1: *Bidens pilosa* L.; Figure S2: *Pterocypsela laciniata* (Houtt.) Shih; Figure S3: The geographical location (Zhenjiang, Jiangsu, China) of the sampling area (square with red) in this study (Map number: GS(2022)4317; produced by the Ministry of Natural Resources of China; http://bzdt.ch.mnr.gov.cn/ (accessed on 6 June 2024)); Figure S4: The picture of some of the garden pots used in this study.

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Abbreviations

IPs	invasive plants
N	nitrogen
PL	monocultural *P. laciniata*
NiPL	monocultural *P. laciniata* treated with nitrate
AmPL	monocultural *P. laciniata* treated with ammonium
UrPL	monocultural *P. laciniata* treated with urea
MixPL	monocultural *P. laciniata* treated with mixed N
BP	monocultural *B. pilosa*
NiBP	monocultural *B. pilosa* treated with nitrate
AmBP	monocultural *B. pilosa* treated with ammonium
UrBP	monocultural *B. pilosa* treated with urea
MixBP	monocultural *B. pilosa* treated with mixed N
PLBP(PL)	co-cultivated *P. laciniata*
NiPLBP(PL)	co-cultivated *P. laciniata* treated with nitrate
AmPLBP(PL)	co-cultivated *P. laciniata* treated with ammonium
UrPLBP(PL)	co-cultivated *P. laciniata* treated with urea
MixPLBP(PL)	co-cultivated *P. laciniata* treated with mixed N
PLBP(BP)	co-cultivated *B. pilosa*
NiPLBP(BP)	co-cultivated *B. pilosa* treated with nitrate
AmPLBP(BP)	co-cultivated *B. pilosa* treated with ammonium
UrPLBP(BP)	co-cultivated *B. pilosa* treated with urea
Mix AmPLBP(BP)	co-cultivated *B. pilosa* treated with mixed N

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