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# Enhanced Primary Productivity in Fenced Desert Grasslands of China through Mowing and Vegetation Cover Interaction

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**Abstract:** To enable grasslands to serve a larger ecological and service role against the backdrop of climate change and human activity, management is essential following long-term fencing. Using desert grassland that had been fenced for 20 years, we conducted experiments on different mowing frequencies (once, twice, and three times a year) and different amounts of vegetation coverage (mowing removal, mowing, and in situ mulch; and mowing, in situ mulch, and additional coverage) and control (no mowing, no removal, and no cover). In 2021 and mid-August 2022, the aboveground biomass, species diversity, and vegetation cover of each species were assessed, and the impacts of species complementarity and competition on the productivity of the fenced grassland were examined. Our findings revealed several significant outcomes: (1) Two and three times of mowing per year promoted growth and development of annual or biennial plants and increased species diversity of the community. (2) The interaction impact of mowing and covering two and three times a year was the most important, as it encouraged compensatory development of plants, particularly the dominant species, and increased aboveground biomass of the fenced grassland ($p < 0.05$). (3) The number of complementary species groups was c. 11% lower for mowing and covering than for mowing removal, indicating that the interspecific relationship for the mowing and covering interaction was dominated by competition, which was more beneficial to the increase in community productivity. (4) *Lespedeza potaninii* Vass. (which dominated the semi-shrubs) and *Agropyron mongolicum* Keng (which dominated the tufted grasses) exhibited compensatory growth, which alleviated the change of mowing disturbance and precipitation fluctuation on the productivity of this grassland ecosystem. (5) Adding vegetation cover after mowing positively influenced community production but did not significantly impact litter decomposition. Our research provides data support for the sustainable development of long-term fenced desert grasslands.

**Keywords:** fenced grassland; mowing; community structure; dominant species; productivity

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## 1. Introduction

Grazing and mowing are the most important human disturbance factors affecting grassland ecosystem characteristics. Studies have shown that long-term overgrazing has seriously damaged the structure of grassland ecosystems and caused a series of ecological problems [1–3]. Since the 1970s, China has attached greater importance to reducing grazing pressure and restoring degraded grasslands in northern China; several policies have been promulgated, including “returning grazing land to grassland” and “ecological compensation” [4]. The large-scale application of these policies provides important benefits for ecosystem restoration. For example, a ban on grazing and the fencing of natural grasslands in northern China have significantly improved productivity of grassland ecosystems [5,6]. However, fenced grassland litter accumulation is also one of the major causes of species extinction and changes in species composition in grassland ecosystems, and threatens ecosystem stability [7]. Therefore, long-term fencing is not always beneficial to grassland health and the sustainable development of grassland animal husbandry [8].

After the implementation of grazing prohibition measures, mowing management has become one of the most important and common grassland utilization methods [9,10]. The mowing process primarily decreases resource utilization by removing the aboveground parts of dominant plants, alters the level of interspecific and intraspecies competition, increases the exposure of low-growing herbs to light, strengthens photosynthesis, and increases relative density, all of which will play roles in compensating the overall biomass of the community [11].

By decreasing the photosynthetic canopy of plant communities and removing aboveground litter, mowing restricts the entry of soil ecosystem carbon, which degrades the soil microhabitat [12,13]. In addition, mowing can reduce the amount of standing litter and litter in the community, and then affect plant growth by changing the surface temperature, humidity, winter snow cover, and other surface environments [14]. These mainly affect the change of dominant species, changing community structure and causing further change of ecosystem functions [15]. The sustainability of grassland ecosystems and the stability of productivity are largely maintained by grassland community diversity [16]. The impact of mowing on grassland community diversity shows differences due to different community types, mowing intensity and frequency, growth conditions, and other factors. Previous studies have shown that infrequent mowing of plants after they have reproduced might lessen the detrimental impacts of fencing on species richness; however, continuous mowing will lead to the increase of mowing-tolerant species and the decrease of mowing-sensitive species, eventually leading to evolution of the grassland community in a new stable state [17–19]. Mowing at the right time can result in better biomass yields as well as beneficial compensatory plant growth, which raises forage biomass in the following year. Plants respond to mowing by compensatory growth, which can be equal, undercompensated, or overcompensated [20]. The productivity of grasslands is increased by moderate mowing, which encourages overcompensated growth in plants. The plants on grasslands show reduced height and individual miniaturization when subjected to an extreme disturbance (mowing), which affects community structure. However, plants can alter their physiological or morphological traits to lessen the negative impacts of external harm [21] and promote compensatory development.

Additionally, soil aggregate structure is easily disrupted after mowing due to the absence of vegetation to buffer the impact of rain or sun exposure. This causes the soil to become more compacted and the number of soil voids to decrease, which is detrimental to soil ventilation [22]. However, while redistributing soil water and fertilizer, air, and heat, adequate land cover can create a barrier layer on the soil surface to stop the exchange of water and heat with the atmosphere. The decomposition of aboveground and underground litter in the following year has a positive impact on the formation of soil humus, and so soil structural properties, net primary productivity (NPP), and water use efficiency can be improved [12,23]. In addition, surface vegetation cover can directly change the contact form between the surface and the atmosphere and prevent loss of soil moisture. Meanwhile, vegetation cover on the surface can play a role in collecting water and conserving soil moisture [24,25]. In addition, studies have shown that vegetation cover can control the longitudinal transport capacity of soil water in the critical water demand period of plant growth, and surface vegetation cover can guarantee a better soil water environment, promote plant growth, and help form high yields [10,26].

Anthropogenic disturbance is gradually changing ecosystems, which may significantly change the makeup of biological communities and impair an ecosystem's ability to perform a steady function and offer a service [27,28]. Maintaining species diversity and community stability is a huge challenge for the sustainable management of grasslands worldwide. It has been asserted that the stability of dominant species influences community stability at least as much as biodiversity [29]. It has been extensively documented how plant community traits and soil physicochemical qualities respond to mowing intensity, frequency, and duration, but little is known about the ecological consequences of vegetation cover on natural grassland following mowing. Therefore, mowing and covering treatments without affecting the material or energy of the ecosystem were used in this study to explore the impact of vegetation productivity on ecosystem stability in fenced desert grassland. The following assumptions were tested: (1) the different mowing intensities and subsequent degrees of vegetation removal influence community structure and productivity and (2) community productivity in the presence of human disturbance is mainly governed by dominating species. This is expected to give management and theoretical foundations for bettering the ecosystem service function of fenced grassland.

## 2. Materials and Methods

### 2.1. Study Site

The study area was located in the desert steppe of the Sidunzi ecological field station of Ningxia in China (37°76′ N, 107°28′ E), with terrain high in the south and low in the north (Figure 1). It is adjacent to the Mu Us Sandy Land in the north and the Loess Plateau in the south; it transits from the hilly area of the Loess Plateau to the Ordos Platform from south to north, and this is a key transition zone of agricultural and pastoral areas in northern China [30]. The topography of the experimental area is flat, with an average elevation of 1600 m, a mean annual temperature of 8.1 °C, an annual precipitation of 289 mm (with more than 60% concentrated in July–September), annual evaporation of 2132 mm, an annual accumulated temperature $\geq$0 °C, which is 3430 °C, and a typical temperate continental climate [31]. The zonal vegetation type is desert grassland, and the zonal soil is calcareous soil, with soil texture mostly sandy soil and silty soil, and with low fertility. Vegetation is mainly xerophytic and mesoxerophytic, mainly *Lespedeza potaninii* Vass., *Agropyron mongolicum* Keng, *Artemisia scoparia* Waldst. et Kit., and *Polygala tenuifolia* Willd. et al. (Table 1). The study area is a desert grassland and the functional groups are classified as subshrubs, perennial herbs (including tufted grass, rhizomatous grass, and herbs), and annual or biennial herbs.

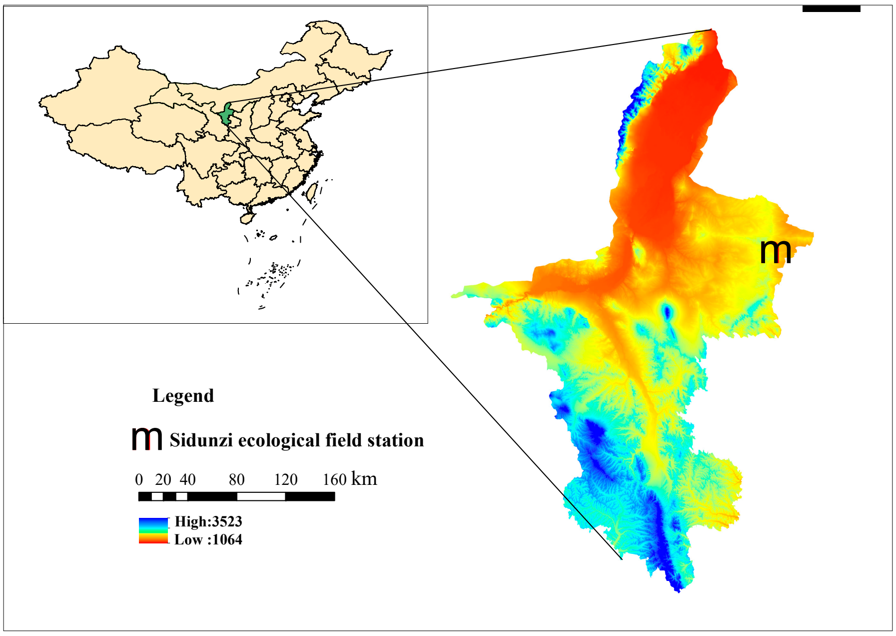

**Figure 1.** Layout diagram of test area.

**Table 1.** Plant composition (Pi) under mowing and covering treatments.

| Functional Group | Species | A1 | A2 | A3 | B1 | B2 | B3 | C1 | C2 | C3 | CK |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Subshrub | *Lespedeza potaninii* Vass. | 0.11 | 0.11 | 0.10 | 0.11 | 0.13 | 0.14 | 0.08 | 0.09 | 0.14 | 0.08 |
| Perennial | *Agropyron mongolicum* Keng | 0.10 | 0.13 | 0.12 | 0.16 | 0.13 | 0.09 | 0.18 | 0.22 | 0.08 | 0.18 |
| | *Polygala tenuifolia* Willd. | 0.06 | 0.03 | 0.04 | 0.04 | 0.05 | 0.04 | 0.05 | 0.05 | 0.05 | 0.02 |
| | *Glycyrrhiza uralensis* Fisch. | 0.02 | 0.01 | 0.03 | 0.02 | 0.01 | 0.02 | 0.01 | 0.02 | 0.02 | 0.02 |
| | *Lipschitzia divaricata* (Turcz.) Zaika, Sukhor. and N. Kilian | 0.01 | 0.01 | 0.06 | - | 0.02 | 0.05 | 0.02 | 0.02 | - | 0.01 |
| | *Echinops gmelinii* Turcz. | - | - | - | - | - | - | - | - | - | 0.01 |
| | *Peganum harmala* L. | - | 0.02 | 0.01 | 0.02 | 0.02 | 0.02 | 0.02 | 0.05 | 0.02 | 0.02 |
| | *Vincetoxicum mongolicum* Maxim. | 0.01 | - | - | 0.01 | - | - | 0.02 | 0.01 | - | - |
| Annual or biennial | *Artemisia scoparia* Waldst. et Kit. | 0.49 | 0.46 | 0.41 | 0.43 | 0.35 | 0.50 | 0.40 | 0.39 | 0.45 | 0.36 |
| | *Euphorbia esula* L. | 0.13 | 0.15 | 0.16 | 0.10 | 0.11 | 0.11 | 0.16 | 0.12 | 0.16 | 0.21 |
| | *Allium mongolicum* Regel | - | - | 0.01 | - | 0.01 | 0.01 | - | 0.01 | - | 0.02 |
| | *Kali collinum* (Pall.) Akhani and Roalson | 0.01 | - | 0.01 | - | 0.02 | 0.02 | 0.02 | 0.02 | - | 0.01 |
| | *Cenchrus echinatus* L. | 0.09 | 0.04 | 0.04 | 0.02 | 0.06 | 0.02 | 0.02 | 0.04 | 0.03 | 0.01 |
| | *Eragrostis minor* Host | 0.01 | 0.01 | 0.01 | 0.03 | 0.01 | - | 0.02 | 0.01 | 0.01 | - |
| | *Euphorbia maculata* L. | - | 0.04 | 0.03 | 0.09 | 0.10 | 0.10 | 0.03 | 0.10 | 0.05 | 0.08 |

Note: Pi = (RDi + RCi + RHi + RBi)/4, RDi represents relative density, RCi represents relative coverage, RHi represents relative height and RBi represents relative biomass.

The experimental area had been fenced since 1 November 2002 to exclude large animals from grazing. The precipitation and temperature during the test are shown in Figure 2.

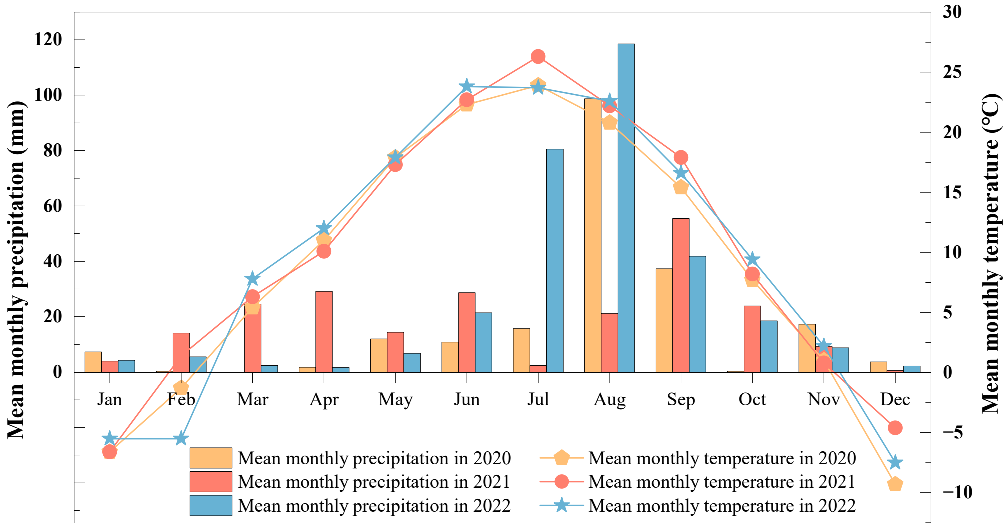

**Figure 2.** Mean monthly precipitation and temperature during the experiment.

### 2.2. Experimental Design

This study utilized temperate fenced desert grassland in Yanchi County in a randomized block design. The four treatments were as follows: mowing and removing vegetation (A1–A3); mowing and in situ mulching (B1–B3); mowing and in situ mulching and adding A, (C1–C3); and the control (CK; no mowing, no removal, and no cover). The additive "A" came from treatment A. Mowing was performed each time using a mower (Honda GXV160, Foshan Maiwei Long Machinery Co.,Guangdong, China) with a stubble height of 2 cm, and each treatment was repeated three times. After each mowing, the vegetation was artificially spread evenly over the plots to be covered according to the experimental design. The A1, B1, and C1 represent mowing once a year; A2, B2, and C2 represent mowing twice a year; and A3, B3, and C3 represent mowing three times a year. The mowing treatment commenced in September 2020, with mowing time in July, September, and November of each year. The C treatment proportionally adds the vegetation removed from the A treatment: in the first mowing, the C1 plots of each block added 1/6 (A1+A2+A3), the C2 plots added 2/6 (A1+A2+A3), and the C3 plots added 3/6 (A1+A2+A3). In the second mowing, the C1 plots of each block were added with 1/6 (A2+A3) of this block, the C2 plots were added with 2/6 (A2+A3), and the C3 plots were added with 3 /6 (A2+A3). In the third mowing, the C1 plots of each block group added their own block 1/6A3, the C2 plots added 2/6A3, and the C3 plots added 3/6A3 (Figure 3). Treatment A was mowing removal, and treatments B and C were mowing and covering interaction treatments, in which C had more vegetation coverage than B.

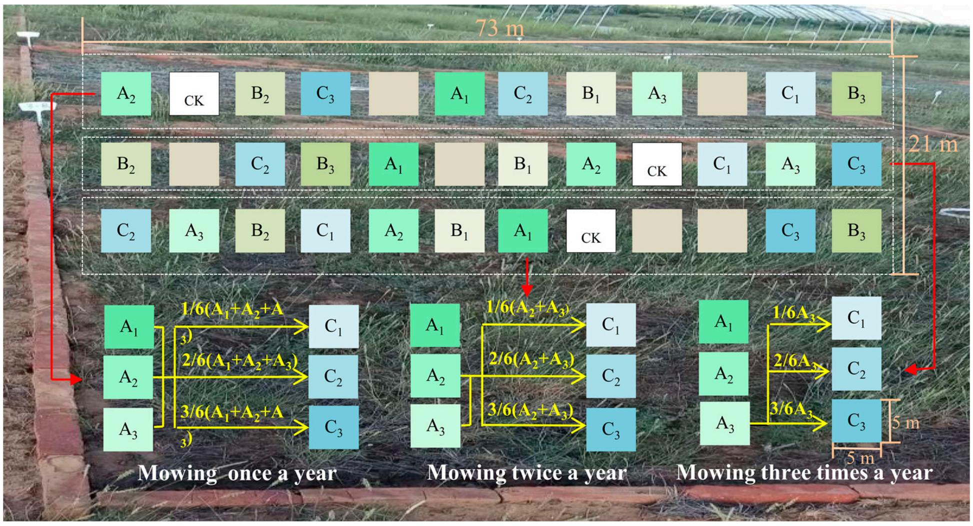

**Figure 3.** Quantity of coverage treatment.

We selected a plot with uniform vegetation growth measuring 73 m × 21 m in a fenced and sealed desert grassland in Yanchi County. Each plot was 5 m × 5 m, walkway spacing between groups was 1.5 m, and the cell spacing within groups was 1 m. To reduce the test error, two plots with uneven vegetation growth were removed from each group, and a total of 30 test plots were used. The vegetation growth status and quantity of each treatment plot were basically consistent, with no significant difference in soil moisture.

### *2.3. Data Collection and Analysis*

Between 2021 and 2022, samples used to determine density (number of individuals of each species in the sample), coverage (acupuncture method), height (measurement of the natural height of 5 plants of each species in the sample), and aboveground biomass (drying and weighing method) were taken using a 1 m × 1 m quadrat randomly placed in each plot without a spatial overlap of quadrats among years and at least 1 m inside the border of each plot to avoid edge effects. This was conducted during 15–20 August (peak sampling of aboveground biomass due to aboveground plant tissues dying during winter). After being categorized by species, all living plants were oven dried at 65 °C for 48 h to a consistent weight, and weighed. In the same quadrat used to quantify aboveground biomass, species richness (defined as the number of plant species per $m^2$) was recorded. The calculation formula and indexes used are as follows:

$$\mathrm{Pi} = (\mathrm{RDi} + \mathrm{RCi} + \mathrm{RHi} + \mathrm{RBi})/4$$

$$\mathrm{RDi} = \mathrm{densityi}/\mathrm{total\ density}$$

$$\text{RCi} = \text{coveragei}/\text{total coverage}$$

$$\text{RHi} = \text{heighti}/\text{total height}$$

$$\text{RBi} = \text{biomassi}/\text{total biomass}$$

$$\text{Shannon–Wiener index (H)} = -\sum\nolimits_{\text{i}=1}^{\text{s}} \text{PilnPi}$$

$$\text{Margalef index (R)} = \frac{\text{S}-1}{\log_{10}\text{N}}$$

$$\text{Pielou index (E)} = \frac{\text{H}}{\ln\text{S}}$$

$$\text{Simpson index (C)} = 1-\sum(\text{Pi})^2$$

The terms relative density (RDi), relative coverage (RCi), relative height (RHi), and relative biomass (RBi) are used in the calculation; S is the total number of species present in each quadrat, Pi is the weighted average of the relative importance of each species inside the quadrat, and N is the total number of individuals belonging to each species.

Maschinski et al. [32] believed that a compensation effect would occur after plants were injured, and defined overcompensation as the phenomenon of biomass and seed yield increase after plants are eaten or mowed. The compensation index was expressed as CI = G/C. Hjalten et al. [33] divided compensation into overcompensation, equal compensation, and undercompensation (Table 2).

**Table 2.** Division of compensatory effects.

| Ratio of Treated Biomass to Control Biomass | Compensatory Effect |
|---|---|
| $G/C > 1$ | Overcompensation |
| $G/C = 1$ | Equal compensation |
| $G/C < 1$ | Undercompensation |

Note: G represents the sum of biomass of each mowing and C represents the biomass of the control group.

The coefficient of variation in each plot was defined as $\mu/\sigma$, where $\mu$ and $\sigma$ are the interannual mean and standard deviation of aboveground biomass, respectively [13].

### 2.4. Statistical Analysis

The calculation of species importance value refers to the method of [34]. Plant productivity and plant diversity indexes of different mowing and covering treatments all used one-way analysis of variance. Pearson correlation analysis was used to determine the biomass complementary relationships between species and functional groups. Linear and polynomial fitting were used to analyze the relationships between biomass and Shannon–Wiener, Margalef, Pielou, and Simpson indexes. Graphs were plotted using Origin 2023.

## 3. Results

### 3.1. Community Aboveground Productivity with Mowing and Covering

The aboveground biomass increased with the number of mowings in the B and C treatments, respectively, when mowing and vegetative cover were combined. The community aboveground biomass treated once and twice a year with mowing and in situ mulch was higher than that treated once and twice a year with mowing, in situ mulch, and additional coverage (Figure 4a). Mowing and removal had the highest coefficient of variation (0.171), followed by mowing and in situ mulching (0.155) and then mowing, in situ mulching, and adding cover (0.140) (Figure 4b).

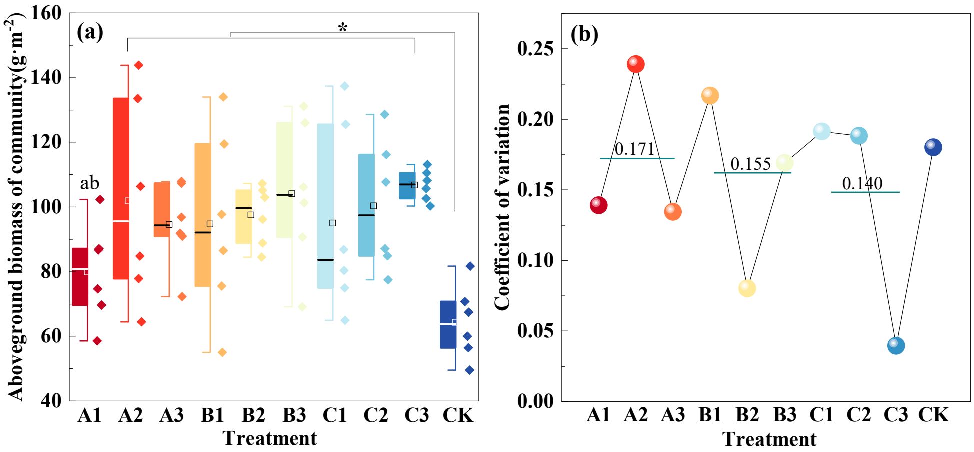

**Figure 4.** Community productivity and coefficient of variation. (**a**) Aboveground biomass of community of treatments, (**b**) coefficient of variation of treatments. The diamond shapes in (**a**) represent treatment data, The shapes in (**b**) represent different treatment. Different lowercase letters indicate significant differences at $p < 0.05$. The same applies to other figures below. * represent the correlation is significant at the $p = 0.05$ level.

Further analysis on the maintenance of stability of community aboveground biomass showed that for mowing and removal and for mowing and covering, the larger was the relative biomass of species (*Ar. Scoparia*, *Ag. Mongolicum*, *L. potaninii*, and *P. tenuifolia*) and the smaller was the variability (Figure 5). In addition, some plant species had a relatively small biomass and large coefficient of variation (Figure 5a,b).

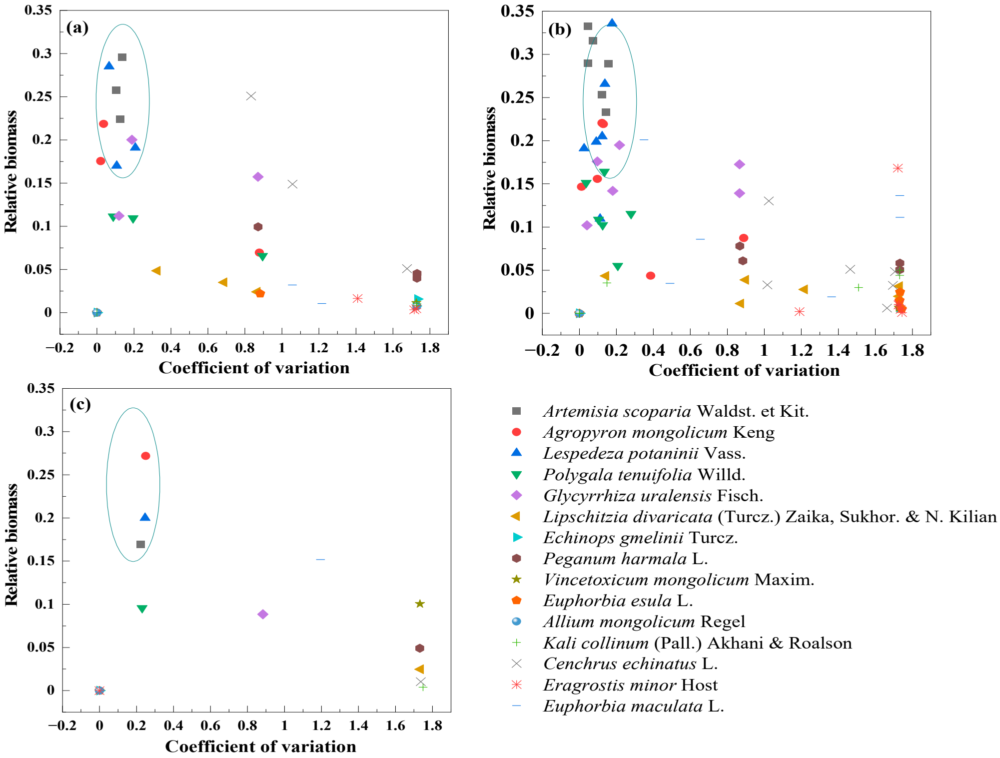

**Figure 5.** Relationship between a species' relative biomass and coefficient of variation. (**a**) Mowing removal, (**b**) mowing and covering, and (**c**) no mowing, no removal, and no covering.

### *3.2. Relationship between Species Diversity and Biomass under Mowing and Covering*

The Shannon–Wiener index showed a strong positive association with community aboveground biomass following mowing and covering treatment ($p < 0.001$) and a significant unimodal correlation with aboveground biomass of the dominant species ($p < 0.05$). The aboveground biomass of the community and the dominating species had a substantial positive connection with the Margalef index ($p < 0.001$). The Simpson index revealed no link between community aboveground biomass and dominant species biomass, but the Pielou index showed a favorable positive association with the community aboveground biomass (Figure 6).

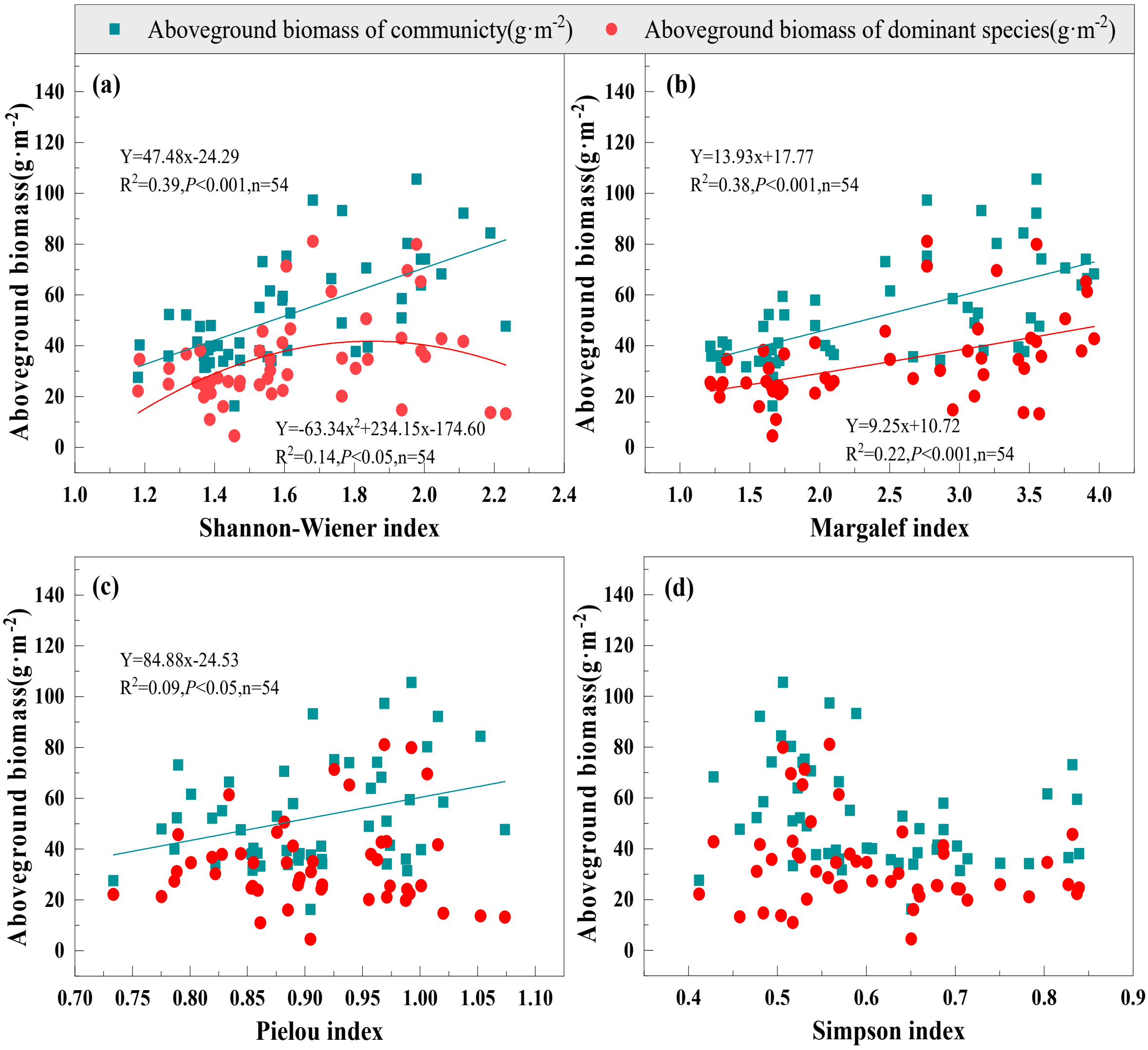

**Figure 6.** Relationship between species diversity and biomass of desert grassland for mowing and mulching treatment. (**a**) The relationship between the Shannon -Wiener index and the aboveground biomass, (**b**) the relationship between the Margalef index and the aboveground biomass, (**c**) the relationship between the Pielou index and the aboveground biomass, (**d**) the relationship between the Simpson index and the aboveground biomass.

### *3.3. Compensation Effects of Mowing and Covering*

Mowing and covering encouraged overcompensatory development of the plants on the fenced grassland. The compensation index increased with the increase of mowing frequency for the mowing and in situ mulching treatment. Compared to once per year mowing and removal, the compensation index for the two and three times a year mowing and in situ mulching treatments increased by 22.45% and 25.05%, respectively ($p < 0.05$); the compensation index for the two and three times a year mowing, in situ mulching, and adding cover increased by 19.14% and 22.72%, respectively ($p < 0.05$) (Figure 7).

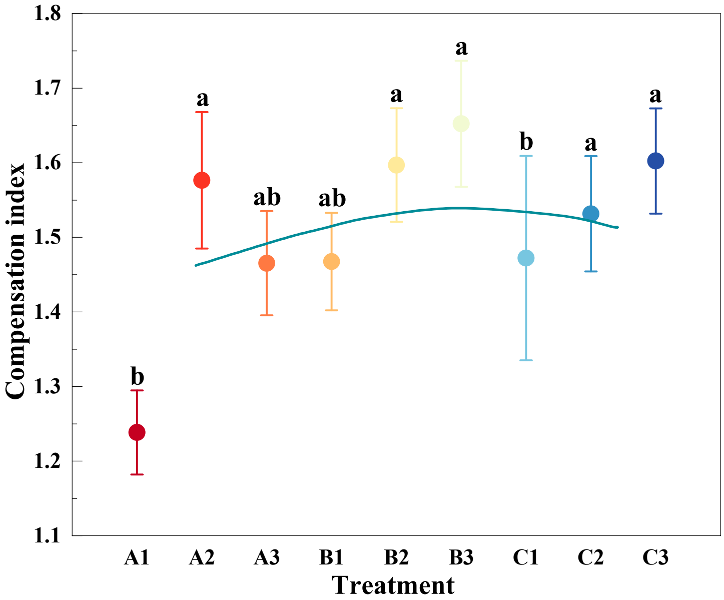

**Figure 7.** Community aboveground biomass compensation effect of mowing and covering treatment. Different lowercase letters indicate significant differences at p < 0.05.

### 3.4. Compensability of Community Productivity of Mowing and Covering

Pearson correlation analysis of the relative biomass of 15 plant species under the mowing and removal treatment showed that 46 species had no significant relationship between species. There were 31 groups with significant negative correlations, accounting for 29.52% of the total groups (Figure 8a), and these groups may have had complementary productivity. Pearson correlation analysis of the relative biomass of 14 species under the interaction of mowing and covering showed 17 groups with significant negative correlations, accounting for 18.68% of the total groups (Figure 8b).

### 3.5. Compensation of Dominant and Sub-Dominant Species with Mowing and Covering

*Agropyron mongolicum* and *L. potaninii* had high negative correlations when treated with mowing and covering (Figure 8). When the relative biomass of *L. potaninii* decreased, the relative biomass of *Ag. mongolicum* increased (Figure 9), confirming compensation between the two species, which compensated for the instability of community biomass caused by the decline in biomass of one species.

### 3.6. Compensation between Dominant and Other Plant Species with Mowing and Covering

*Agropyron mongolicum* and eight other species showed negative correlations under the treatment of mowing and removing, and *L. potaninii* and five other species had negative correlations (Figure 8a). *Agropyron mongolicum* and four other species had negative correlations when mowing and covering were combined, as did *L. potaninii* and seven other species (Figure 8b). These negatively correlated species somewhat offset the variation in community production due to the shifting biomass of dominant species. Therefore, from the perspective of community productivity, these negatively correlated species are merged, and these populations formed a complementary relationship with the relative biomass of two dominant populations (*Ag. mongolicum* and *L. potaninii*). Further analysis showed that the combination of these species with *Ag. mongolicum* (or *L. potaninii*) supplemented the fluctuation of *L. potaninii* (or *Ag. mongolicum*) biomass, thus maintaining stability of the grassland community (Figure 10).

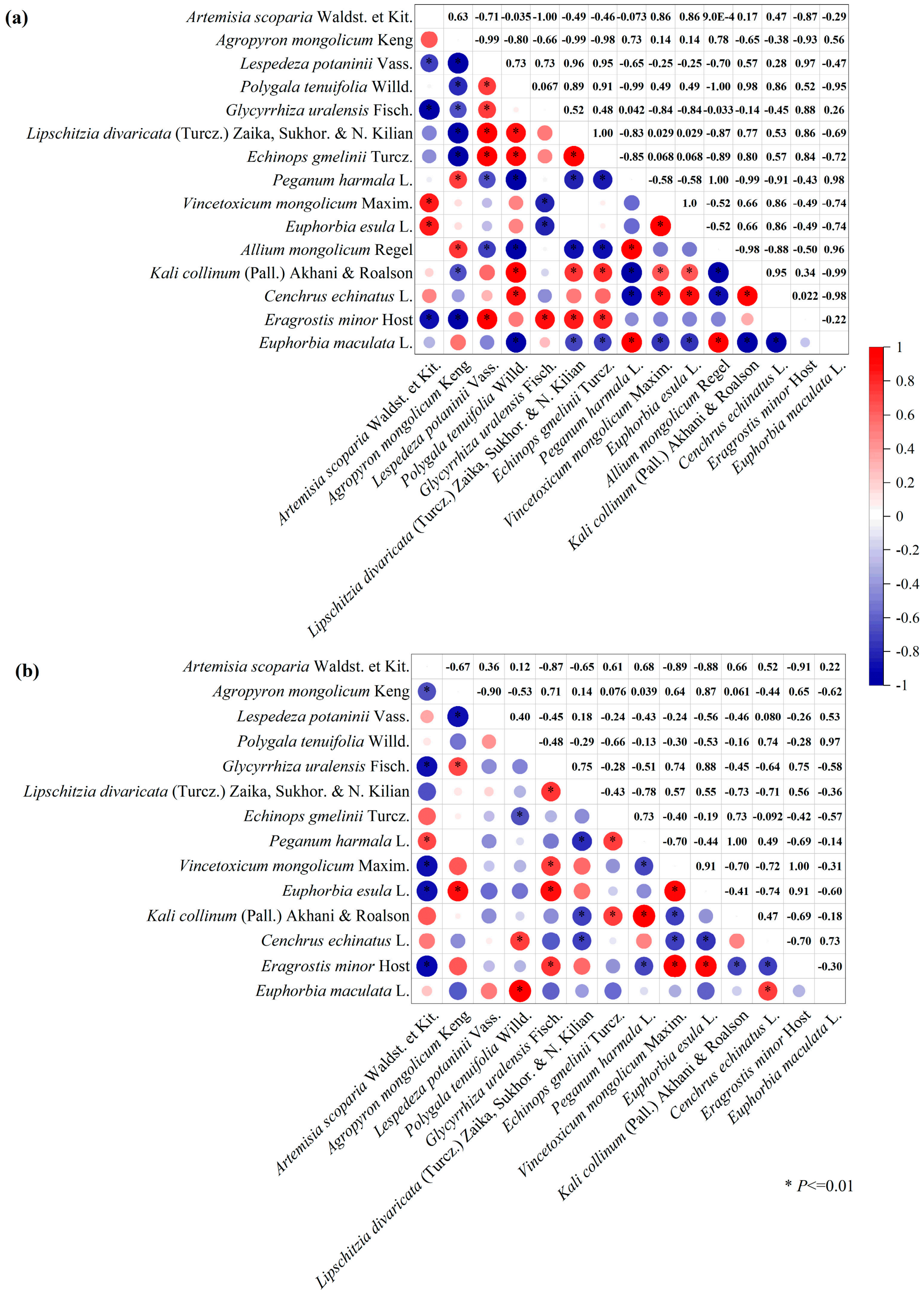

**Figure 8.** Complementary analysis of relative biomass of mowing and covering. (**a**) Mowing removal, (**b**) mowing and cover vegetation interaction.

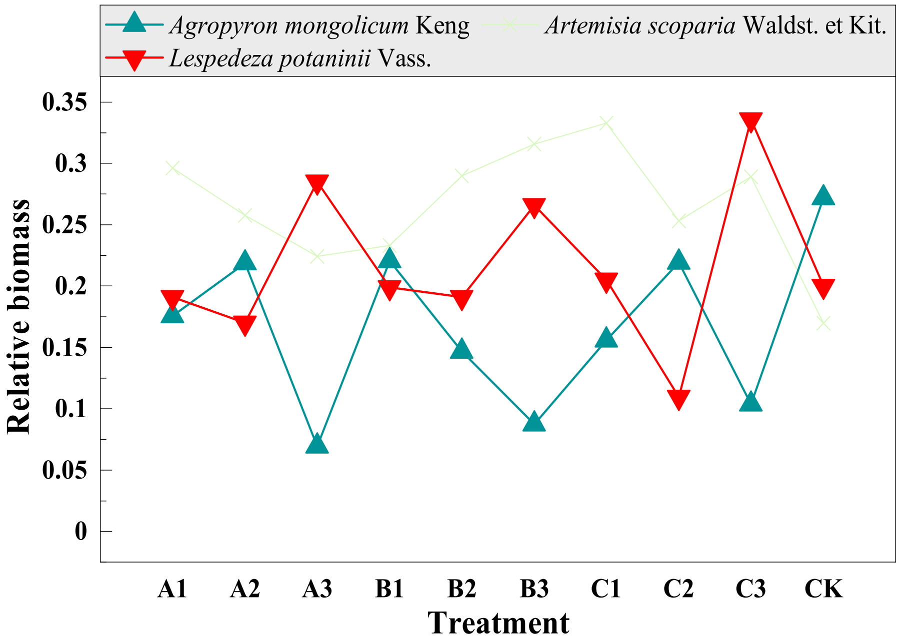

**Figure 9.** Complementary analysis of the relative biomass of dominant and sub-dominant species for mowing and covering.

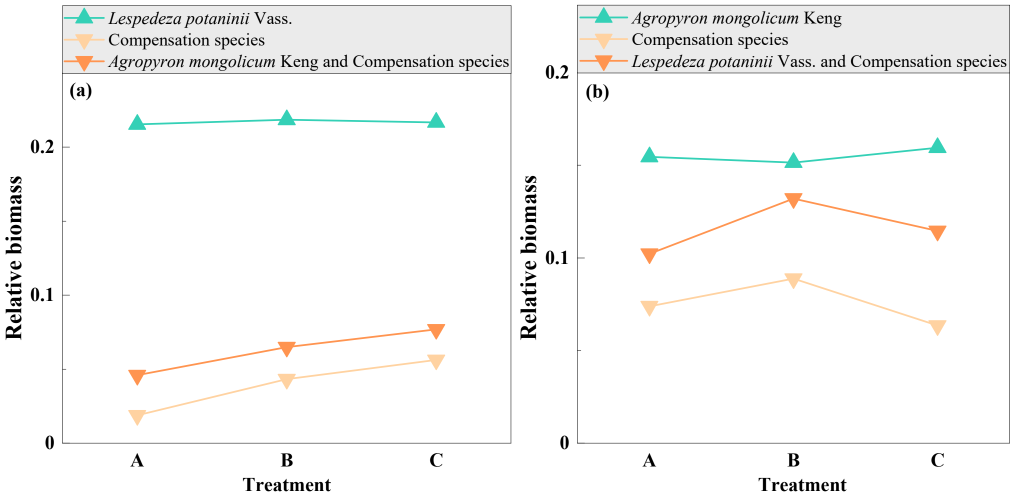

**Figure 10.** Compensation analysis between dominant and compensatory species. (**a**) Complementary relationship between *L. potaninii* and compensating species, (**b**) complementary relationship between *Ag. mongolicum* and compensating species.

### *3.7. Compensability between Functional Plant Groups with Mowing and Covering*

Vegetation may be broken down into subshrubs, perennial herbs (including tufted grass, rhizomatous grass, and herbs), and annual or biennial herbs in the research region. The productivity compensation between functional groups of desert grassland plants under mowing and covering treatment was examined. There was a negative connection between the subshrubs dominated by *L. potaninii* and the tufted grasses dominated by *Ag. mongolicum*, a very strong negative correlation between tufted grasses and rhizomatous grasses, and large negative correlations between annual or biennial grasses and subshrubs and rhizomatous grasses under the mowing and removal. Only subshrubs and herbs exhibited a very strong negative connection when mowing and covering were combined (Table 3).

**Table 3.** Complementarities between biomass of desert grassland functional groups.

| | Subshrubs | Tufted Grasses | Rhizomatous Grasses | Herbs | Annual or Biennial Herbs |
|---|---|---|---|---|---|
| Subshrubs | 1 | −0.57 (−0.53) | 0.67 * (0.15) | 0.53 (−0.90 **) | −0.74 * (0.40) |
| Tufted grasses | | 1 | −0.92 ** (−0.13) | 0.52 (0.21) | 0.64 * (0.56) |
| Rhizomatous grasses | | | 1 | −0.62 (−0.30) | −0.64 * (−0.54) |
| Herbs | | | | 1 | 0.43 (−0.60) |
| Annual or biennial herbs | | | | | 1 |

Note: Data indicated outside of the brackets are the complementarities between the biomass of functional groups under the mowing and removal; the data in brackets are the complementarities between the biomass of functional groups under the interaction of mowing and covering. *, $p < 0.05$, **, $p < 0.01$.

## 4. Discussion

We investigated effects of mowing and covering on natural community biomass and dominant species compensatory growth in a fenced desert grassland in China and found that mowing helped boost aboveground biomass. The interaction treatment of mowing and covering with greater frequency had the most pronounced effect, consistent with studies performed in temperate steppes [35]. The relative biomass coefficient of variation for mowing and covering was lower than that for mowing and removing, indicating that the community's aboveground biomass fluctuation was largely steady: that is, plant cover can preserve the relative stability of community aboveground biomass in desert grasslands despite disruption from mowing [36]. However, we acknowledge that the plot area in our study (5 m × 5 m, separated by 1 m or 1.5 m aisles) may not be large enough for plants and soil to completely avoid the interaction among the plots, as plants such as *Ag. mongolicum* may have lateral root or rhizome growth which can possibly transfer nutrients among plots. The extent of impacts that the possible transfer of nutrients among the plots have on the community aboveground biomass performance warrant further studies, possibly using large plots. Further analysis of community biomass stability revealed that variability decreased as relative species biomass increased (i.e., *L. potaninii*, *Ag. Mongolicum*, *Ar. Scoparia*, and *P. tenuifolia*), demonstrating that dominant and sub-dominant species played a significant role in the community's function and that even minor variability under interference will contribute to stability of the entire community [37,38]. Additionally, some plant species with relatively low biomass and high coefficients of variation can mitigate the effects of extreme fluctuations in biomass of the dominant species on productivity of the entire grassland. These species' rapid rates of reproduction also serve to buffer instability of the productivity of the entire grassland community, which helps maintain stability of the grassland ecosystem [37]. The species richness with mowing and in situ mulching was higher than that for mowing removal and mowing, in situ mulching, and adding coverage, indicating that moderate mowing after long-term fencing was beneficial to plant community composition [13]. The Margalef index demonstrated significant positive biodiversity–biomass relationships, demonstrating a positive correlation between species richness and productivity under low-resource environments in fenced desert grasslands, consistent with the findings of most research sites on Inner Mongolian grassland [39]. After two years, *Kali collinum* (Pall.) Akhani and Roalson, and *Cenchrus echinatus* L. and other species, started to appear in the mowed desert grassland, because mowing removes some biomass from aboveground parts of tall plants and damages their vegetative organs, photosynthetic capacity, and competitiveness [11,12], and mowing reduces soil organic matter (C and N) by removing aboveground biomass, thus reducing plant residues that can return to soil and photosynthetic C transfer to roots. Additionally, mowing eliminated the shelter provided by standing litter and the accumulation of litter in the community, enhancing the light and water conditions for lower-level plants, expanding the opportunities for new seeds to come into contact with the soil, and fostering the growth and development of annual or biennial dwarf plants [40]. It was also confirmed that mowing disturbance can change the interspecific relationship by increasing spatial heterogeneity [39], thereby changing diversity of communities, and reducing litter is also beneficial for germination of dormant seeds in soil and the regeneration and reproduction of species [41]. After two years of mowing and covering, the newly emergent annual or biennial herbs did not clearly contribute to the community, because the rarest species, which make up the majority of a community, may have little impact on community composition due to their low abundance [39].

The plant community displayed overcompensated growth, but the positive effect of mowing removal was weak in the mowing and covering treatment, possibly because mowing removes a significant amount of nutrients (e.g., nitrogen, phosphorus, and potassium) from the plant's aboveground parts, reduces the nutrients in soil, and ultimately affects community aboveground biomass [17]. The interaction of mowing and covering two and three times a year was beneficial to the increase of grassland NPP, but this increase was weakened by adding cover, showing that too much vegetation coverage on the soil surface is unfavorable to the accumulation of plant nutrients [35]. The reason may be that under the interactive treatment of mowing and covering of grassland, the vegetation cover on the surface is the only carbon source input to the soil, and a large amount of nitrogen is required in the process of vegetation decomposition [42], causing a carbon and nitrogen imbalance in the process of vegetation decomposition, in turn intensifying the nitrogen competition between microorganisms and plants, which is not conducive to plant growth [43]. Mowing encourages the growth of more new tissues, which increases the net photosynthetic rate and NPP, and also removes aboveground biomass of tall plants as well as the tops of the middle and lower layers of plants, eliminating any height advantage [11]. Community production will continue at a relatively consistent level when the decrease in biomass of tall plants is about equivalent to the rise in biomass of the middle and lower layers, and may be why *Ag. mongolicum* grew tall, *L. potaninii* grew short, and the dominant species were asynchronous after mowing in the study area.

Research found that the stability of NPP declined in desert grasslands [44] because grassland productivity is closely related to local climate conditions (such as precipitation) in addition to being affected by management measures [45,46]. It is generally believed that the north of China is warm and humid [47,48], and the "rainfall threshold" required for the rapidly responsive *Ar. scoparia* is low [49], making it vulnerable to the impact of inter-annual rainfall fluctuations (Figure 2). Long-term sentinel experiments are needed to study more closely the effects of mowing and mulching on the productivity of desert grassland vegetation. Additionally, this species can extremely easily develop into a beneficial species in the area and has a high ability to adapt to severe situations. We found that a substantial negative connection between dominating species under mowing and mulching was discovered in a supplementary investigation of species' relative biomass. Compared with mowing and removing, 14 pairs of species with negative correlations between relative biomass of mowing and mulching were reduced, indicating that under mowing and mulching, the compensation between species was weak, but there may be greater competition [50]; the species with negative correlations supplement the fluctuation of community productivity caused by the change of biomass of dominant species.

Species' compensatory growth properties are beneficial to community productivity because decreased biomass in one species can be compensated by increases in others [51,52], thus maintaining productivity of the grassland community. As a result, from the perspective of community productivity, these species with negative correlations formed a complementary relationship with the relative biomass of the two dominant species (i.e., *Ag. mongolicum* and *L. potaninii*). The functional categories of desert grasslands exhibited varying degrees of productivity complementation and had a substantial compensatory connection with the dominant plant species for mowing removal and for the interaction of mowing and mulching. The complementary analysis of biomass among functional groups showed that the species mainly compensated each other with the mowing and removal, and the competition was dominant under the mowing and covering interaction.

## 5. Conclusions

For a fenced desert grassland, this study clarified how mowing and covering plants affected productivity and compensatory growth across species. The results showed that the interaction of mowing and covering twice and three times a year has particularly encouraged compensatory growth of dominant species, increasing the aboveground biomass of fenced desert grasslands. However, we acknowledge that long-term sentinel experiments are needed to study more closely the effects of mowing and mulching on the productivity of desert grassland vegetation. Concerning the tufted grasses *Ag. mongolicum* and *L. potaninii*, which were predominantly semi-shrubs, compensatory growth helped to reduce the amplitude of change in community productivity caused by mowing disturbance. Long-term field study is needed to further understand how community structure and species diversity affect productivity in a fenced desert grassland. The results of this study can provide robust data support and essential theoretical guidance for promoting the sustainable utilization of fenced desert grasslands and the functioning of grassland ecosystems in arid and semi-arid zones.

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