Trade-off Strategy of Three Dominant Species in Grazing Exclusion of Desert Steppe,china

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Abstract

Background and Aims

Grazing exclusion is a powerful measure to restore the ecological environment in desert steppe. Studying the changing trend of functional traits and trade-off strategy about dominant species what is of great significance to understand the effect of grazing exclusion on species succession. Methods We studied that the change of leaf and root functional traits of three dominant species (Lespedeza potaninii, Agropyron mongolicum and Stipa breviflora) under different term of grazing exclusion.

Results

We found that the leaf area and leaf nitrogen content, leaf dry matter content, total root length, specific root length and specific root surface of Lespedeza potaninii in grazing were higher than grazing exclusion. The highest specific leaf area, specific root length of Agropyron mongolicum and Stipa breviflora were observed in short-term grazing exclusion. Leaf tissue density and root tissue density significantly decreased in short-term grazing exclusion. Economic spectrum exist, Lespedeza potaninii have more conservation strategy in short-term grazing exclusion compared with grazing. Agropyron mongolicum and Stipa breviflora have more acquisition strategy in grazing exclusion. Average diameters have great effected on above-ground biomass.

Conclusion

The result showed that grazing exclusion change leaf and root functional traits of three dominant species, different species have different trade-off strategy.

Highlights

- Leaf functional traits and root functional traits of three dominant species showed no-liner trend under different term of grazing exclusion
- Leaf economic spectrum exist, multi-dimension root economic spectrum also exist
- Different species have different trade-off strategies. *Lespedeza potaninii* have more conservation strategy. *Agropyron mongolicum* and *Stipa breviflora* have more acquisition strategy

Introduction

In the process of long-term succession, functional traits are the core attributes of plants with environmental changes and it can affect the function of the ecosystem (Hongguang et al. 2015; Sánchez-Gómez et al. 2013). Functional traits is a bridge between plants and the environment, which reflect the indicative role of plants in ecosystem functions. Plant functional traits are correlated with the survival and growth strategies of plants under different environment. It reflect the ability of plants about acquisition and conservation of resource(Diaz et al. 2004). As two main organs of plants, leaf and root functional traits always been studied.

Leaves are the organ that are sensitive to environmental change. Showed the ability about photosynthesis, primary production and water exchange of plants(Bernhardt-R Mermann et al. 2008; Violle et al. 2007). It's had great significance to understand the succession strategies of plants in ecosystem changes that to study the changing trend of leaf functional traits under different environment conditions(Westoby and Wright 2006). Different filter of natural environment have different effect on functional traits. The response of leaf traits to temperature change was that the leaf area decreased with the decrease of temperature, while the leaf dry matter content increased(Yang et al. 2011; Yichen et al. 2017). Some studies showed that plant have higher specific leaf area and lower leaf dry matter content under high-water input environment(Funk et al. 2021; Sánchez-Gómez et al. 2013); Some results showed that the relationship between specific leaf area, leaf nitrogen content and water showed a negative correlation(Liu et al. 2020; Pérez-Camacho et al. 2012). Besides, leaves have lower specific leaf area, leaf nitrogen content in infertility area; while leaf dry matter content and leaf tissue density became higher(Khan et al. 2020; Ordoñez et al. 2009). In addition to natural environmental filter, man-made environment also affects leaf traits such as grazing and grazing exclusion(An and Guoqi 2015; Li et al. 2015). In the study of the effect of grazing on leaf traits, it was found that the leaf area and specific leaf area decreased, and the leaf dry matter content increased under heavy grazing(Wang et al. 2016; Wang et al. 2020). Meanwhile,we found that different species have different change strategies in different grazing intensity(Bullock et al. 2001; Wei et al. 2009). Grazing exclusion reduced disturbance factors of grassland, plants had higher leaf size and specific leaf area. While leaf dry matter content became lower within a certain period of grazing exclusion(Amiaud et al. 2008; Zhang et al. 2018). Besides, root plays an important role in plant growth as the organ under-ground part. Whether transported water and soil nutrients or transferred carbon nutrients, root have great effect(García Verdugo et al. 2020; Smith et al. 2014). Different filters also have effected on root functional traits. Drought was positively correlated with root diameter, and negatively correlated with specific root length and specific surface area(Zhou et al. 2018; Zhou et al. 2019). The more resources available in soil, plants had higher specific root length and root nitrogen content(Freschet et al. 2017; Pan et al. 2018). In the study of the effect of grazing. it was found that root diameter, length and surface area increased under moderate grazing intensity which accorded with the "moderate disturbance hypothesis"

(Wei et al. 2009).

At the same time, the phenomenon have been found that plant functional traits are not a single change, but a traits group formed by the coupling of multiple traits. The group is called "economic spectrum", which reflects the acquisition and conservation resources strategy of plant(Ishizawa et al. 2021; Wright et al. 2004). Leaf economic spectrum is divided into two axis that the plant had small leaf area, low leaf nitrogen content, high leaf dry matter mass content and leaf tissue density at the conservative axis of the resource(Reich 2014). While the plant had large leaf area, high nitrogen content and large specific leaf area at the resource acquisition axis(Carvajal et al. 2018; Cornwell et al. 2010). In the same way, some scholars believe that plant also have root economic spectrum. At one axis of the root economic spectrum, the root length is smaller, and the average diameters and tissue density of root is higher; at the other axis, plants should be thin roots with high nitrogen content, specific root length and large surface area(Funk et al. 2017; Lozano et al. 2020). However, part of scholars found that root diameter, specific root length and other traits are independent of root economic spectrum. So they support the opinion that root economic spectrum is not one-dimensional, but multi-dimensional(Kramer-Walter et al. 2016; Valverde-Barrantes and Blackwood 2016). As the two major organs of plants, the coordination relationship between leaf and root has always been controversial. some studies have shown that the whole plant have an economic spectrum, other studies have shown that the relationship between leaf and root traits are an orthogonal relationship. So the relationship still needs to be further studied among them(Collins et al. 2016; Kembel and Cahill 2011).

Trade-off strategies of plant were correspond to environmental changes, thus affecting the function of the ecosystem. Biomass is the important index of ecosystem function , the changes of traits will affect the biomass(Cadotte 2017; Finegan et al. 2015). During ecosystem, biomass increased with the increase of leaf nitrogen content, while decreased with specific leaf area(Čierniková et al. 2021; Yang et al. 2011). Other studies have shown that specific leaf area and leaf nitrogen content are positively relationship with biomass and leaf dry matter mass is negatively relationship with biomass (Garbowski et al. 2020). Among the root functional traits, root diameter, root tissue density and root nitrogen content were positively correlated with biomass, while root length and specific root length were negatively correlated with biomass(Hanisch et al. 2020).

Many studies are mainly focused on environmental change gradient and grazing management that were effected on plant functional traits. But study on functional traits in grazing exclusion what change were less. To understand leaf and root function traits varied among different term of grazing exclusion and the trade-off strategy. We selected three dominant species (*Lespedeza potaninii*, *Agropyron mongolicum* and *Stipa breviflora*) as research objects. Measured three dominant species leaf and root functional traits among different term of grazing exclusion at desert steppe. The purpose of study was to explore (1) the changed trend of leaf and root functional traits under different term of grazing exclusion; (2) the trade-off strategies of three dominant species under the term of grazing exclusion ; and (3) the main factors affected above-ground biomass in plant functional traits.

Materials And Methods

Site description

The study area is located in desert steppe, where is located in Yan chi County, Ningxia province (37°04'~38°10' N,106°03'~107°04' E). The area is linked between the arid and semi-arid area. The study area belongs to a temperate continental semiarid climate. The mean annual temperature is 8.1℃, total annual precipitation is 250-350mm, mainly occurring in summer season; the annual evaporation is 2710mm, the annual frost-free period is 165d. The zonal soils are loessial and light sierozem, and the azonal soils are sandy arenosol, alkaline saline and meadow soil, all poor in fertility with loose structure and very susceptible to wind erosion. The vegetation is characterized by desert steppe, distributed with *Agropyron mongolicum*, *Stipa breviliora*, *Lespedeza potaninii*, *Glycyrrhiza uralensis*, *Leymus secalinus*, *Cynanchum komarovii* and so on.

Experiment design

We chosen three sites which have similar soil and altitude characterize. The long term grazing grassland (GG), The livestock rate is 2.38 sheep.hm^{-2}. The short-term grazing exclusion(SGE) and the long-term grazing exclusion(LGE) were selected for this study. The short-term grazing exclusion since 2011, the long-term grazing exclusion since 2003.The three sites information was investigate and recorded.

Table 1 Geographic details of the three sites and vegetation characteristics at each site

	Longitude	Latitude	Above-ground biomass (g.cm^{-2})	Coverage(%)	Density (plant.cm^{-2})
GG	106°56'45.25"E	37°56'48.35"N	72.66±5.97	57.67±0.67	264.33±53.05
SGE	106°59'55.85"E	37°55'55.78"N	140.67±4.93	70.00±2.65	453.00±6.43
LGE	107°01'16.68"E	37°58'22.17"N	87.13±18.12	75.50±7.2	976.50±446.58

According the previous study (Table2), A*gropyron mongolicum*, *Stipa breviliora*, *Lespedeza potaninii* were chosen in the study.

Table 2 Important value of three dominant species

	Lespedeza potaninii	*Agropyron mongolicum*	*Stipa breviliora*	Sum
GG	0.26	0.17	0.23	0.65
SGE	0.23	0.29	0.04	0.56
LGE	0.32	0.13	0.07	0.53

GG, Grazing grassland; SGE, Short-term grazing exclusion; LGE, Long-term grazing exclusion

Sample collection and measurement

During August 5-10, 2018, we conducted our plant samples. leaf functional traits were measured. We set five 1m×1m plots in each site, each plot selected randomly 6 individuals of every species, 5 healthy leaves of each individual were conducted. The collected leaves were placed in the middle of the wet filter paper, packed in a plastic bag, sealed and put into a foam box with an ice bag (temperature < 5℃) and brought back to the laboratory for character determination. Put the leaves into a sealed bag filled with water, put them in the refrigerator at 5℃for 12 hours, dry the surface water with filter paper, weigh the saturated fresh weight of the leaves, measure the leaf area with a portable leaf area meter, then kill the green 15min at 105℃, dry the leaves to constant weight at 65℃, and weigh the dry weight of the leaves. The dried leaves were ground into powder by ball mill, and the N content of leaves was determined. Specific leaf area (SLA) = leaf area / leaf dry weight, leaf dry matter content (LDMC) = leaf dry weight / leaf saturated fresh weight, Leaf tissue density (LTD) = leaf dry weight / leaf volume. Besides, to measure the coverage and density of each species, then cut each species separately on the ground and brought back to the laboratory and dry it at 65℃ to a constant mass.

Meanwhile, used a self-made sampler to dig out 25∏x40 cm soil columns to determine the plant root soil columns, sift out the large soil blocks with a sieve (be careful not to break the roots), put them in a sealed bag and bring them back to the laboratory. The collected soil was washed repeatedly, the miscellaneous roots were picked out, and the washed roots were scanned with win RHIZO to get the root length, average root diameter, root surface area and other indexes. The scanned root was dried in an envelope to dry weight, and the dried root was ground into powder with a ball mill to determine the root N content. Specific root length (SRL) = root length / root dry weight, Specific surface area (SRA) = root surface/root dry weight, Root tissue density (RTD) = root dry weight /root volume.

Data analysis

Before the analysis of variance of the data, the normality and homogeneity of variance of the data are tested, and the log transformation is carried out for the data that do not conform to the normality. One-way ANOVA was used to analyze the relationship between grazing exclusion and function traits of leaves and roots of dominant species. Pearson and PCA was used to analyze the correlation between functional traits and plant growth strategies.“Relative importance analysis”was used to analyze the relationship between functional traits and above-ground biomass.“Relative importance analysis”refers to the quantification of an individual contribution to a multiple regression model .

Results

Changes in leaf functional traits

The leaf area and leaf nitrogen content, leaf dry matter content of *Lespedeza potaninii* in GG were higher compared with that other term of grazing exclusion (Fig. 1a, e). The highest leaf area value of *Agropyron mongolicum* and *Stipa breviflora* were observed in LGE.The leaf nitrogen content of S*tipa breviflora* was significantly different between GG and LGE. (Fig. 1a, b). Leaf tissue density of three dominant species decreased in short-term of grazing exclusion and then increased in long-term grazing exclusion (Fig. 1c). The specific leaf area of *Lespedeza potaninii* was significantly lower in GG than that in SGE and LGE; The highest specific leaf area value of *Agropyron mongolicum* and *Stipa breviflora* were observed in SGE,while the leaf dry mass content were lowest (Fig. 1d, e).

Changes in root functional traits

The lowest total root length of *Stipa breviflora* was observed in short-term grazing exclusion. Grazing exclusion significantly increased total root length for *Agropyron mongolicum* (Fig. 2a). Average diameters and root tissue density of *Lespedeza potaninii* showed that no significantly different among different term of grazing exclusion. Average diameters of *Agropyron mongolicum* and *Stipa breviflora* in GG were lower compared with that other term of grazing exclusion(Fig. 2b). The highest root nitrogen content in LGE for three dominant species (Fig. 2c). *Lespedeza potaninii* in GG was characterized by higher total root length, specific root length and specific root surface compared with other term of grazing exclusion (Fig.2a, d, e). Specific root length of *Agropyron mongolicum* and *Stipa breviflora* first increased in short-term grazing exclusion and then decreased in long-term grazing exclusion. The specific surface area of *Stipa breviflora* in SGE significantly different with other term of grazing exclusion(Fig. 2d). The lowest root tissue density of *Agropyron mongolicum* and *Stipa breviflora* were observed in SGE (Fig. 2f).

Trade-off among leaf and root functional traits

LDMC has a significant negative correlation with SLA ($P<0.05$); and significant positive correlation with LTD ($P<0.01$). There was a significant positive correlation between LA and LNC($P<0.05$). SRL was significantly positively correlated with SRA and TRL ($P<0.01$), negatively correlated with RNC ($P<0.05$), and negatively correlated with RTD and AD ($P<0.01$). RTD was significantly positively correlated with AD ($P<0.05$), also significantly positively correlated with RNC ($P<0.01$). There was a significant negative correlation between TRL and AD ($P<0.05$), and extremely significant negative correlation with RNC ($P<0.01$). LA and LNC ware significantly positively correlated with SRL ($P<0.05$), TRL ($P<0.01$). LA and LNC were significantly negatively correlates with AD,RNC ($P<0.05$). and an extremely significant negative correlation with RTD ($P<0.01$). LNC was positively correlated with SRA ($P<0.05$).

PCA results show that the first principal component axis and the second principal component axis together explain 86.5% of the variables（Fig.4a）. The first principal component axis explained 60.1% of the variables, which was positively correlated with LA, LNC, SRL, SRA and TRL, and negatively correlated with RNC, RTD and AD. The second principal component axis explains 25.6% of the variables in total, which is related to LTD, LDMC and SLA. The two PC axes clearly defined that three dominant species were arranged by different term of grazing exclusion. Under different term of grazing exclusion , analysis of *Agropyron mongolicum* and *Stipa breviliora* is on the positive correlation side of PC axes 1, while *Lespedeza potaninii* is on the negative correlation side of PC axes 1.

Relative importance of leaf and functional traits to above-ground biomass

The relative importance of 11 functional traits to above-ground biomass is shown in Figure 5. The relative contribution rates of AD, LA, and LDMC are all above 10%. AD is the most important at 19.36%, and the importance of LA is 16%. The lowest importance of SRA is 4.51%. AD is the highest important factor.

Discussion

Effects of different term of grazing exclusion on leaf functional traits

Compared with other organs, leaves are more sensitive to environmental changes. Leaf functional traits were characterized that plants use the strategies among different environments (Funk et al. 2021; Violle et al. 2007b). Leaf area and specific leaf area are related to plant photosynthetic capacity and are relationship with plant relative growth rate (Wei et al. 2009). Plant have the stronger ability of photosynthetic in richer resources of area. The leaf area of *Agropyron mongolicum* and *Stipa breviflora* in long-term grazing exclusion that more lager, also confirmed this opinion (Khan et al. 2020; Yang et al. 2011). While the leaf area and leaf nitrogen content of *Lespedeza potaninii* in grazing is higher than others, which is related to the selective feeding of livestock. *Lespedeza potaninii* has better palatability, which makes livestock eat more, thus promoting the compensatory growth of plants(An and Guoqi 2015). Specific leaf area is positively correlated with the rate of carbon assimilation of plants (Amiaud et al. 2008). Plant have higher specific leaf area under abundant resources, so the specific leaf area of three dominant species in grazing exclusion more higher than grazing. And the highest specific leaf area of *Agropyron mongolicum* and *Stipa breviflora* were observed in short-term grazing exclusion, which indicated that the specific leaf area increased not accordingly with increased the term of grazing exclusion (Zhang et al. 2018). Leaf dry matter content and leaf tissue density are related to plant structure and tissue, indicating the potential growth rate of plants (Sánchez-Gómez et al. 2013; Yue et al. 2019). Species had higher leaf dry matter content and leaf tissue density indicated that more resource were used to maintain nutrients and defence construction under infertile environment (Ordoñez et al. 2009; Wei et al. 2009). The phenomenon support the view that leaf dry matter content and leaf tissue density of three dominant species in grazing exclusion were lower compared with grazing. While the leaf dry matter content of *Agropyron mongolicum* and *Stipa breviflora* that not significantly change between grazing and short-term grazing exclusion. The result showed that leaf dry matter content is an inert trait of Gramineae plants with the changing environment (Wang et al. 2016; Ye et al. 2020a; b). And leaf tissue density of three dominant species is lowest in short-term grazing exclusion. The reason is that leaf traits significantly change within certain term of grazing exclusion, and change of traits were not obvious or worse after long-term grazing exclusion that environment tend to be stable (Zhang et al. 2018). Leaf nitrogen content is closely related to photosynthesis and relative growth rate of plants. The leaf nitrogen content in long-term grazing exclusion of *Stipa breviflora* is higher than grazing, indicating that leaf nitrogen content is positively correlated with environmental factors (Du et al. 2019; Wang et al. 2016). In the study, we also found that leaf functional traits in non-linear trend(Sandel et al. 2016).

Effects of different term of grazing exclusion on root functional traits

As under-ground organ of plant, root have an important impact on plant colonization, survival and distribution pattern (Zhou et al. 2019). Total root length is one of the basic index, which reflected the ability of root to absorb nutrients and water. The total root length of *Agropyron mongolicum* increased with the increase term of grazing exclusion, which indicated that the ecological environment became improved (Ordoñez et al. 2009). The total root length of *Lespedeza potaninii* in grazing was significantly higher than that in grazing exclusion. The reason that feeding selectively of livestock and the return of soil nutrients promoted the compensatory growth of *Lespedeza potaninii* (An and Guoqi 2015; Zhou et al. 2019b). Average root diameter is an index used to reflected defense tissue construction of plants. In resource-poor areas, plants increase their ability to obtain water and nutrients from soil by thickening root diameter to maintain their own growth(García Verdugo et al. 2020). This theory was also confirmed by the fact that the average diameters of *Agropyron mongolicum* and *Stipa breviflora* in the grazing was thicker than that in grazing exclusion. But *Lespedeza potaninii* was affected by its own phylogenetic structure and the hysteresis by the root system of the main root type plants, so that the average root diameter did not significantly change(Pan et al. 2018). Resource acquisition plants tend to have higher specific root length. The specific root length of *Agropyron mongolicum* and *Stipa breviflora* increased in short-term of grazing exclusion (Zhang et al. 2018); the specific root length of *Lespedeza potaninii* in grazing was higher, which was related to strategy selectively of plant(Valverde-Barrantes and Blackwood 2016). Under term of grazing exclusion, the specific root surface of root increased(Collins et al. 2016). Root nitrogen content an important element in plant roots, which is related to root respiration rate. The root nitrogen content of the three species were the highest in long-term grazing exclusion,indicated that grazing exclusion increased the nitrogen content of root (Cadotte 2017; Collins et al. 2016). Root tissue density is the defense tissue of root system and the index of extension. The high root tissue density indicates that is beneficial to the conservation of resources. The root tissue density of *Agropyron mongolicum* and *Stipa breviflora* in short-term grazing exclusion is decreased. The result showed that short-term grazing exclusion is benefit root growth. But the root tissue density not decreased with the increased term of grazing exclusion, the reason is that long-term grazing exclusion intensified the competition among species. Due to the influence of its own phylogenetic and the delay change of root traits, the root tissue density of *Lespedeza potaninii* no significant different(Zhou et al. 2018).

Trade-off strategies among plant functional traits

In response to the changes of environmental factors, plant functional traits were coupled to form different comprehensive traits under different environmental conditions. The functional groups reflect the changes of plant survival and growth strategies, indicating the balance of investment in plant growth and nutrient conservation (Wright et al. 2004). Leaf functional groups was called “leaf economic spectrum”. According the cost-benefit theory, leaf increased the investment in growth while decreased the cost of survival. The relationship existed among leaf traits. Leaf area and leaf nitrogen content reflected the ability of growth, so the two indices showed positively relationship. The two indices represent self-defense tissue structure between leaf dry matter content and leaf tissue density, so positive relation exist among them. Our results confirm these theory. The negatively relationship exist between specific leaf area and leaf dry matter content because that leaf increased the investment in growth while decreased the investment in survival (Funk et al. 2021; Jing et al. 2019; Reich 2014).These relationship reflected the exist of leaf economic spectrum in desert steppe.

Root traits are the same as leaf traits, and there is a correlation between them. Many stuy showed that the positively relationship among specific root length and specific surface area, total root length. Three indices always exist positive relation because represent the ability of root growth. Average diameters and root tissue density all reflected root structure, so the positively relationship exist among them. Our results were consistent with this. Root economic spectrum showed negatively relationship between specific root length and root tissue density, our result confirm it (Valverde-Barrantes and Blackwood 2016). In the relationship of one-dimensional economic spectrum, there was a positive correlation between root nitrogen content and specific root length and specific surface area, but this study found that the correlation between root nitrogen content and its correlation was negative. this is because the trait and functional information of different root orders of different species will affect the correlation between root functional traits (Zhou et al. 2018).

Both leaf and root have economic spectrum, but the coupling relationship between the two economic spectrum not clear. Some studies believe that existed the whole plant economic spectrum; some study believe that leaf and root economic spectrum were independent In this study, there was a positive correlation between leaf area, leaf nitrogen content and specific root length, indicating that with the increase of leaf photosynthetic capacity, the supply of root resources increased and root traits changed. However, there was no correlation between other leaf traits and root traits, especially the specific leaf area and specific root length. The reason is that the leaf traits in desert steppe are affected by environmental factors, while the root system located under-ground is affected by many factors such as its own phylogenetic structure.The influenced factors are different, so leaf and root traits are not entirely coordinate (Kembel and Cahill 2011; Zhou et al. 2018).

According result of principal component analysis, plant have higher leaf area, leaf nitrogen content, specific root length, specific surface area and total root length on the acquire end. Plant have higher root nitrogen content, root tissue density and average diameters on the conserve end. The PCA result showed that three dominant species have different resource strategies, Leguminosae of *Lespedeza potaninii* is at the conservative end of resources, Gramineae of *Agropyron mongolicum* and *Stipa breviflora* are at the resource acquisition end. Compere with strategy in grazing, Gramineae of *Agropyron mongolicum* and *Stipa breviflora* step to resource acquisition end in grazing exclusion. However,the strategy of *Lespedeza potaninii* more conservation in short -term grazing exclusion. We also found that the first principal component was mostly related to root traits, because plant more invested in root to survive in the desert steppe.

Main leaf and root functional traits affecting above-ground biomass

Trade-off strategies of plant were affecting the function of the ecosystem. Above-ground biomass is regarded as an important index of ecosystem function , the changes of traits will affect the above-ground biomass(Cadotte 2017; Fajardo and Siefert 2016; Finegan et al. 2015). During ecosystem, biomass increased with the increase of leaf nitrogen content, while decreased with specific leaf area(Comas et al. 2013; Yang et al. 2011). And above-ground biomass is the product of photosynthesis, so these three leaf characters have great influence on above-ground biomass (Wang et al. 2016). Root diameter is the root trait of an important channel for plants to transport water and nutrients, and it also has a great effect on above-ground biomass(Hanisch et al. 2020).

Conclusions

In the study, we investigated the leaf and root functional traits across three dominant species under different term of grazing exclusion. We found that the leaf area and leaf nitrogen content, leaf dry matter content, total root length, specific root length and specific root surface of *Lespedeza potaninii* in grazing were higher than grazing exclusion. The highest specific leaf area, specific root length of *Agropyron mongolicum* and *Stipa breviflora* were observed in short-term grazing exclusion. Leaf functional traits and root functional traits also exist trade-off. Plant economic spectrum exist in desert steppe. Average diameters and leaf area have great effected on above-ground biomass. Otherwise, Three dominant species have different strategy under term of grazing exclusion.*Lespedeza potaninii* have more conservation strategy; *Agropyron mongolicum* and *Stipa breviflora* have more acquisition strategy

Declarations

Author's contribution

J. L., H. B., and Y. S. designed the experiment. J. L conducted the experiment and Y. Z and Q.L. assisted the field measurements. J. L. analyzed the data and wrote the manuscript, and H.B and Y. S revised the manuscript. All authors provided comments on the manuscript and the revisions and approved the final version

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Figures

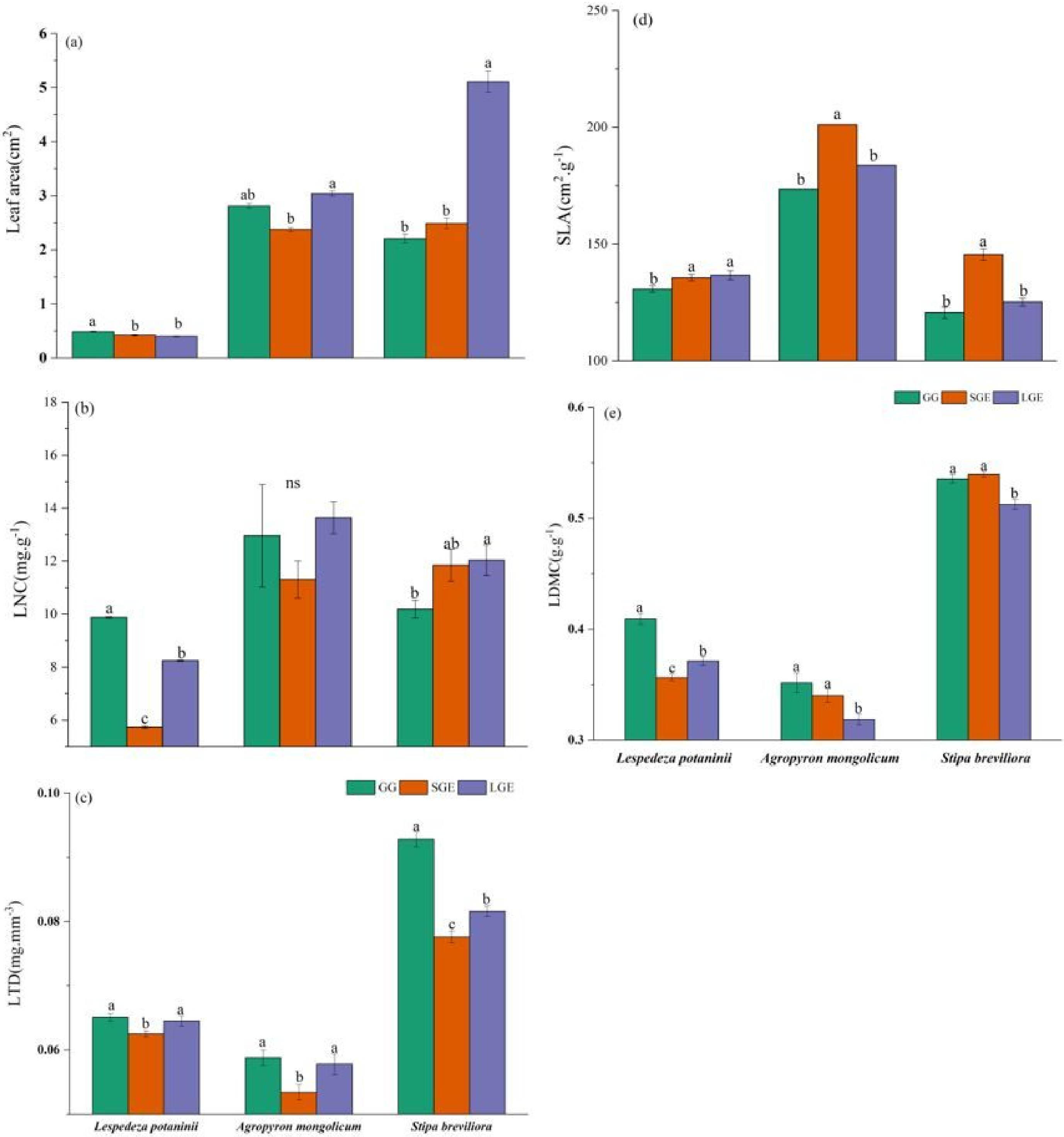

Figure 1

Effect of different term of grazing exclusion years on leaf functional traits. Different letters indicate significant difference among different fencing years (P<0.05). GG: Grazing grassland; SGE: Short-term grazing exclusion; LGE: Long-term grazing exclusion. Leaf area (a), Leaf nitrogen content (b), Leaf tissue density (c),Specific leaf area (d), Leaf dry matter content (e)

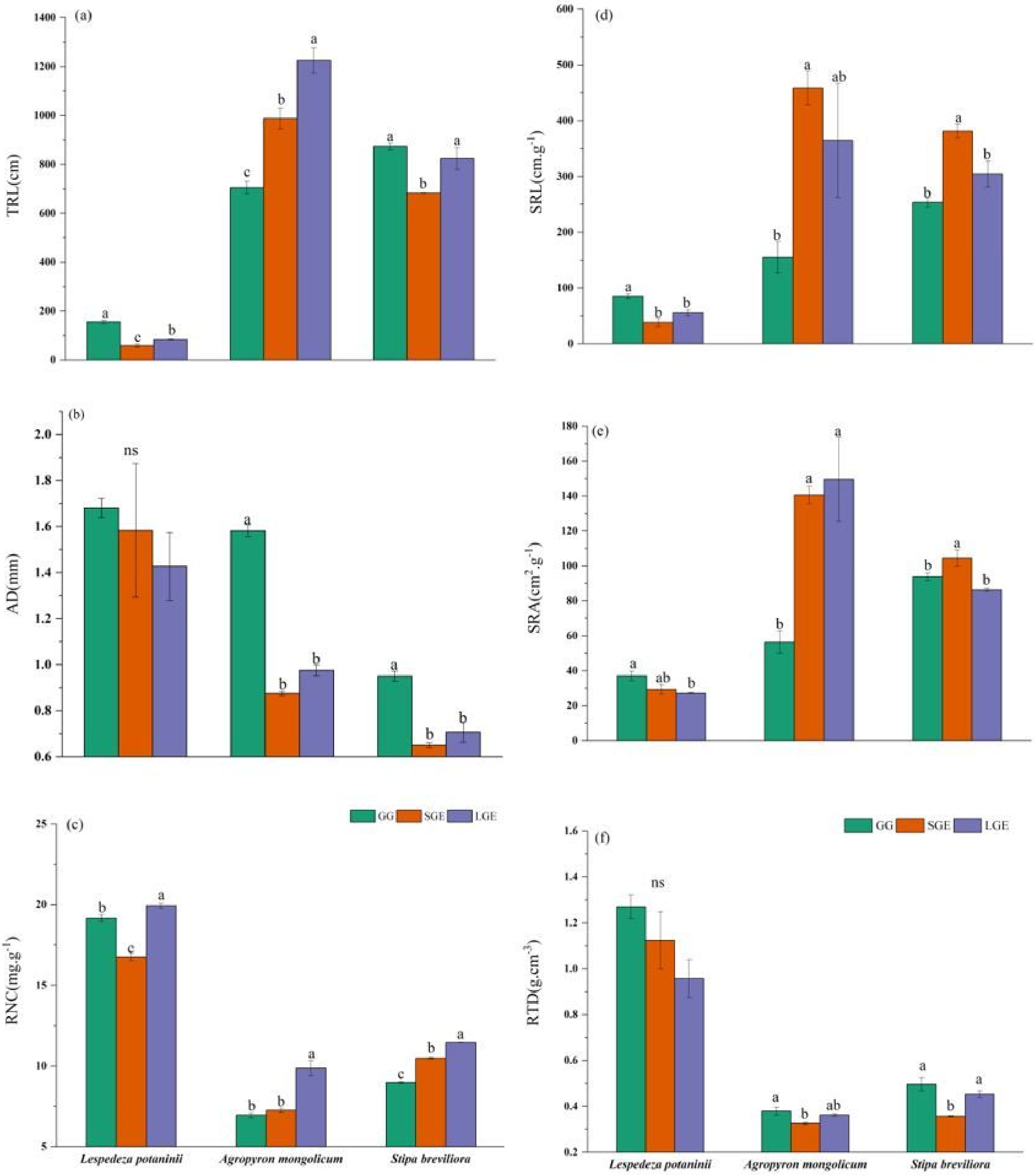

Figure 2

Effect of different term of grazing exclusion on root functional traits. Different letters indicate significant difference among different fencing years (P<0.05). GG: grazing grassland; SGE: Short-term grazing exclusion; LGE: Long-term grazing exclusion. Total root length (a), Average diameter (b), Root nitrogen content (c), Specific root length (d), Leaf tissue density (f)

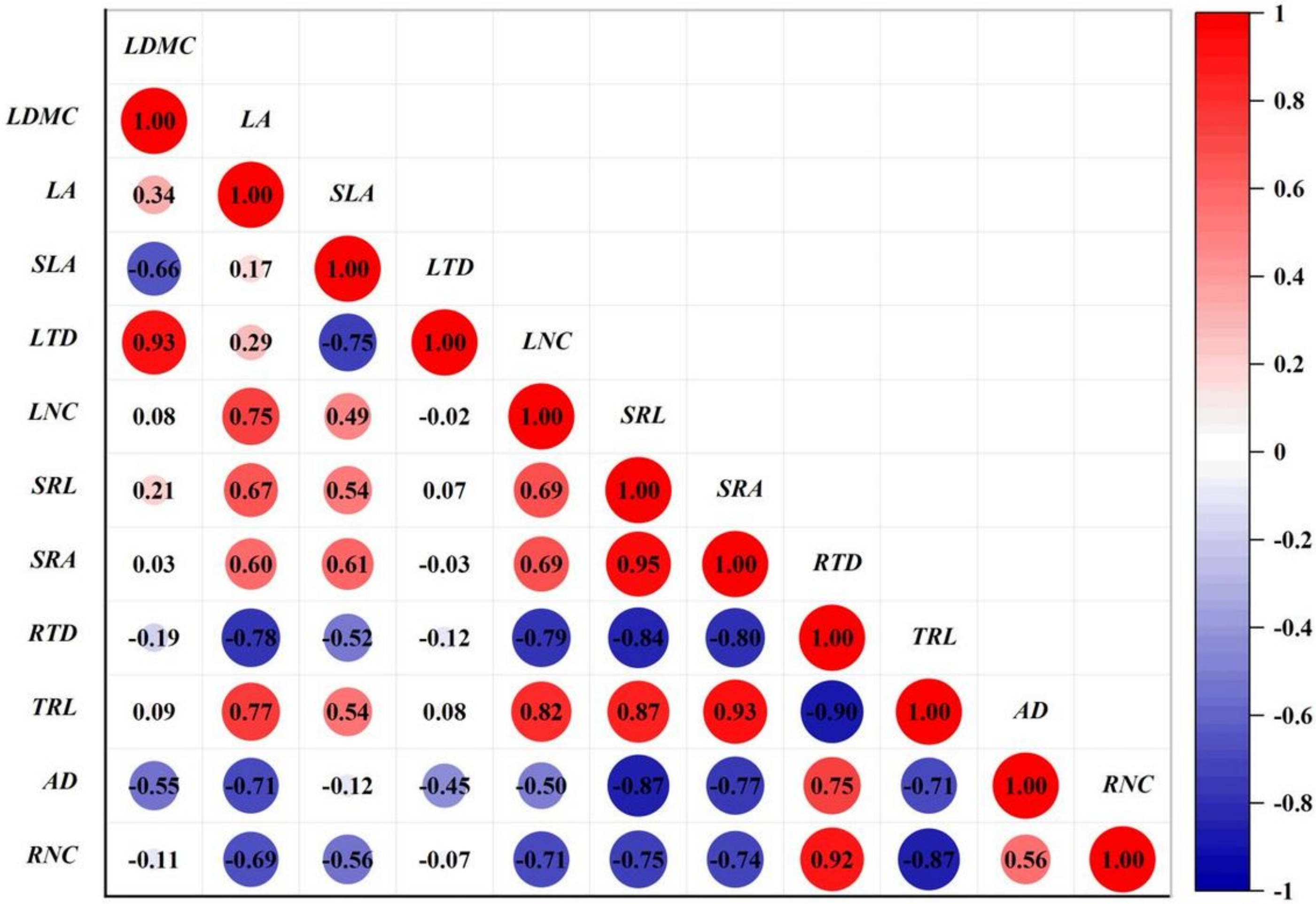

Figure 3

The relationship among leaf and root functional traits. Red = positive relationship, Blue=negative relationship. The strength of the relationship were reflected by the intensity of the color and size of circle. LDMC = Leaf dry matter content; LA = Leaf area; SLA=Specific leaf area; LTD= Leaf tissue density; LNC=Leaf nitrogen content; SRL=Specific root length; SRA=Specific root area; RTD=Root tissue density; TRL=Total root length; AD=Average diameter; RNC=Root nitrogen content

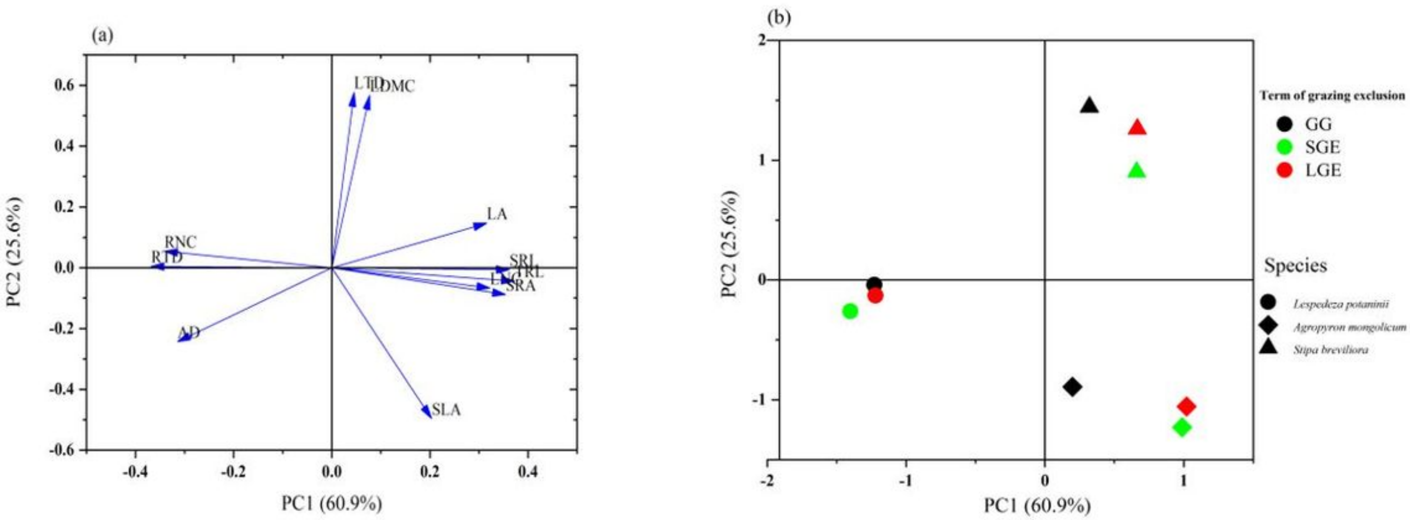

Figure 4

Principal component analysis (PCA) of three dominant species based on leaf and root functional traits we measured(a). The percentages in the axis labels indicate the variance explained by the axis. PC axes 1 and PC axes 2 explain 60.9%and 25.6% of the total variation, respectively. GG: Grazing grassland; SGE: Short-term grazing exclusion; LGE: Long-term grazing exclusion. LDMC=Leaf dry matter content; LA=Leaf area; SLA=Specific leaf area; LTD=Leaf tissue density; LNC=Leaf nitrogen content; SRL=Specific root length; SRA=Specific root area; RTD=Root tissue density; TRL=Total root length; AD=Average diameter; RNC=Root nitrogen content. Analysis of three dominant species under different term of grazing exclusion(b)

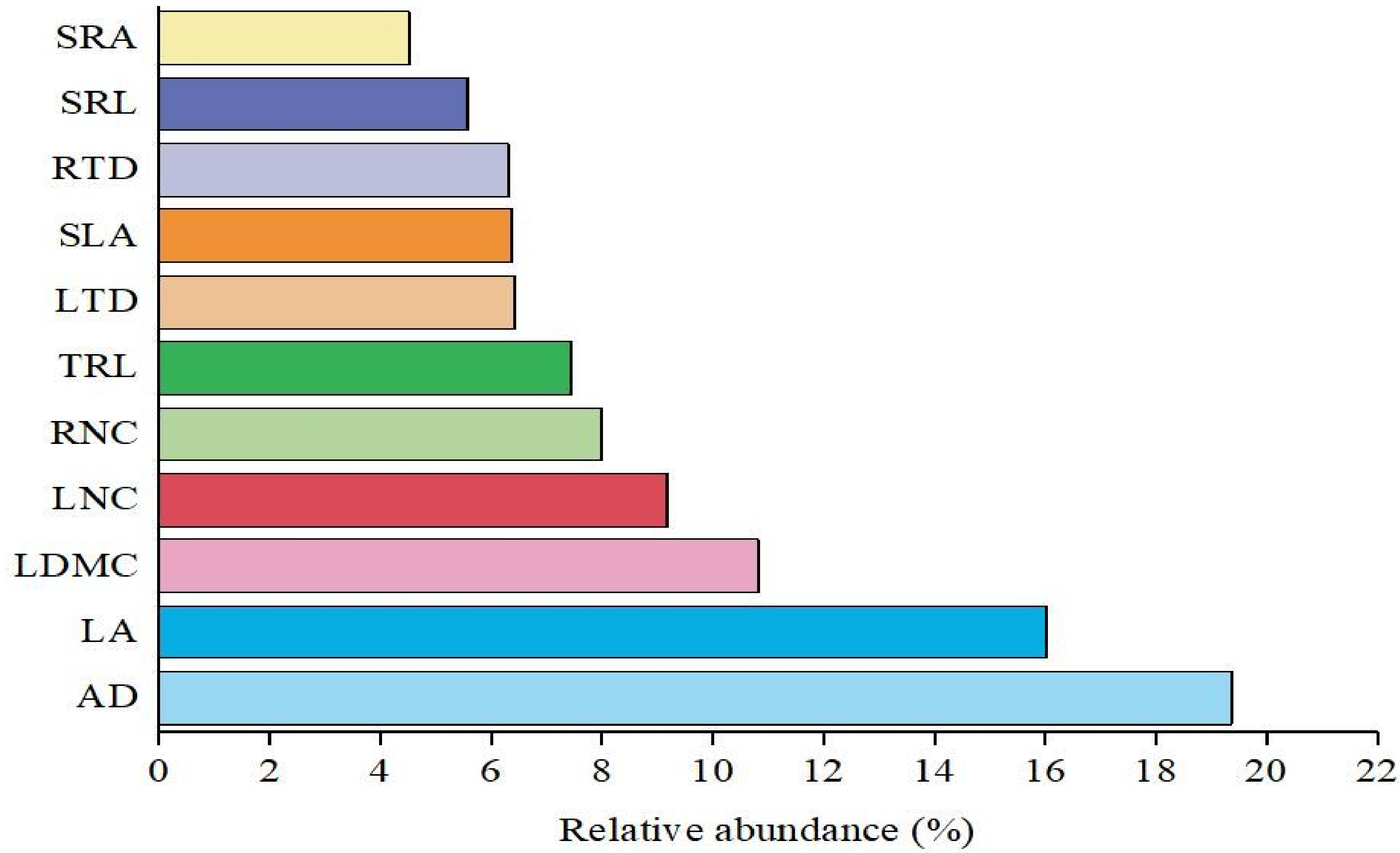

Figure 5

Relative importance value of leaf and root functional traitsLDMC=Leaf dry matter content; LA=Leaf area; SLA=Specific leaf area; LTD=Leaf tissue density; LNC=Leaf nitrogen content; SRL=Specific root length; SRA=Specific root area; RTD=Root tissue density; TRL=Total root length; AD=Average diameter; RNC=Root nitrogen content