Divergent Water Sources of Three Dominant Plant species following Precipitation Events in Enclosed and Mowing Grassland Steppes

Tiejun Bao [1, 2, 3], **Yunnuan Zheng** [1, 2, 3], **Ze Zhang** [1, 2, 3], **Heyang Sun** [1, 2, 3], **Ran Chao** [1, 2, 3], **Liqing Zhao** [1, 2, 3], **Hua Qing** [1, 2, 3], **Jie Yang** [Corresp., 1, 2, 3], **Frank Yonghong Li** [1, 2, 3]

[1] Inner Mongolia University, School of Ecology and Environment, Hohhot, China

[2] Inner Monoglia University, Ministry of Education Key Laboratory of Ecology and Resource Use of the Mongolian Plateau, Hohhot, China

[3] Inner Monoglia University, Inner Mongolia Key Laboratory of Grassland Ecology, School of Ecology and Environment, Hohhot, China

Corresponding Author: Jie Yang
Email address: jyang@imu.edu.cn

Understanding of the dynamic patterns of plant water use in a changing environment is one of foci in plant ecology, and can provide basis for the development of best practice in restoration and protection of ecosystem. We studied the water use sources of three coexisting dominant plant species *Leymus chinensis*, *Stipa grandis* and *Cleistogenes squarrosa* growing in both enclosed and mowing grassland in a typical steppe. The oxygen stable isotope ratios (δ^{18}O) of soil water and stem water of these three species were determined, along with soil moisture, before and after precipitation events. The results showed that (1) mowing had no significant effect on the soil moisture and its δ^{18}O, whereas precipitation significantly changed the soil moisture though no significant effect detected on its δ^{18}O. (2) *C. squarrosa* took up water majorly from top soil layer due to its shaollow root system; *L. chinensis* took up relative more water from deep soil layer, and *S. grandis* took up water from the middle to deep soil layers. (3) *L. chinensis* and *S. grandis* in mowing grassland tended to take up more water from the upper soil layers following precipitation events, but showed no sensitive change in water source from soil profile following the precipitation in the enclosed grassland, indicating a more sensitive change of soil water sources for the two species in mowing than enclosed grassland. The differences in root morphology and precipitation distribution may partly explain the differences in their water uptake from different soil layers. Our results have important theoretical values for understanding the water competition among plants in fluctuating environment and under different land use in the typical steppe.

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4 **Tiejun Bao[1,2,3], Yunnuan Zheng[1,2,3], Ze Zhang[1,2,3], Heyang Sun[1,2,3], Ran Chao[1,2,3], Liqing Zhao[1,2,3], Hua**

5 **Qing[1,2,3], Jie Yang[1,2,3] , Frank Yonghong Li[1,2,3]**

6 [1]School of Ecology and Environment, Inner Mongolia University, Hohhot 010021, China;

7 [2] Ministry of Education Key Laboratory of Ecology and Resource Use of the Mongolian Plateau, Inner Monoglia University,

8 Hohhot, 010021, China;

9 [3] Inner Mongolia Key Laboratory of Grassland Ecology, School of Ecology and Environment, Inner Monoglia University,

10 Hohhot, 010021, China.

11 Corresponding Author:Jie Yang[1,2,3]

12 Street Address, Hohhot,Inner Mongolia, 010010, China

13 Email address:jyang@mail.imu.edu.cn

14 Abstract

15 Understanding of the dynamic patterns of plant water use in a changing environment is one of foci in plant ecology,

16 and can provide basis for the development of best practice in restoration and protection of ecosystem. We studied

17 the water use sources of three coexisting dominant plant species *Leymus chinensis, Stipa grandis* and *Cleistogenes*

18 *squarrosa* growing in both enclosed and mowing grassland in a typical steppe. The oxygen stable isotope ratios

19 ($\delta^{18}O$) of soil water and stem water of these three species were determined, along with soil moisture, before and after

20 precipitation events. The results showed that (1) mowing had no significant effect on the soil moisture and its $\delta^{18}O$,

21 whereas precipitation significantly changed the soil moisture though no significant effect detected on its $\delta^{18}O$. (2) *C.*

22 *squarrosa* took up water majorly from top soil layer due to its shaollow root system; *L. chinensis* took up relative

23 more water from deep soil layer, and *S. grandis* took up water from the middle to deep soil layers. (3) *L. chinensis*

24 and *S. grandis* in mowing grassland tended to take up more water from the upper soil layers following precipitation

25 events, but showed no sensitive change in water source from soil profile following the precipitation in the enclosed

26 grassland, indicating a more sensitive change of soil water sources for the two species in mowing than enclosed

27 grassland. The differences in root morphology and precipitation distribution may partly explain the differences in

28   their water uptake from different soil layers. Our results have important theoretical values for understanding the

29   water competition among plants in fluctuating environment and under different land use in the typical steppe.

30   **Keywords:** Steppe; Dominant plants; Water sources; Mowing; Oxygen stable isotopes

31

Introduction

33   Utilization of different water sources by plants is one of key mechanisms underlying plant

34   species coexistence and plant community construction (Zhang *et al*., 2014). The main water

35   sources for plant utilization are precipitation, soil water, runoff water and groundwater (Duan *et*

36   *al*., 2007). The proportion of various water sources in plant water uptake depends on many

37   factors, such as topography, land use type, soil texture and the pattern, intensity and frequency of

38   precipitation. For example, it was observed that a single strong precipitation event could increase

39   the availability of the water in deep soil layers, which in turn facilitated the growth of deep-

40   rooted plant species (Nippert *et al*., 2007; Goldstein *et al*., 2014). Plants have varied utilization

41   efficiencies for various water sources in different ecosystems. In the desert ecosystem of

42   southern Utah, USA, Ehleringer *et al.* (1991) found that the growth of annual and perennial

43   succulent plants depended entirely on summer precipitation, whereas herbaceous and perennial

44   woody plants could use both summer and winter-spring precipitation, with herbaceous plants

45   having more dependence on summer precipitation. Analyzing plant water sources helps

46   understanding of the adaptation mechanisms used by different species to cope with the arid

47   environment, thus providing a basis for accurately addressing the root water uptake when

48   constructing hydrological models. In addition, these analyses can also, according to the spatial

49   and temporal differences in plant water sources, provide guidance for species selection and

50   matching in revegetation to avoid excessive competition among species. Currently, the studies

51   about the use of water sources by plants have been widely conducted in deserts, temperate forests

52   (Halliday *et al*., 2011), Mediterranean-type deserts (Matimati *et al*., 2013) and coasts (Mccole *et*

53   *al*., 2007; Corbin *et al*., 2005).

54   The temperate semi-arid steppe is one of the most important ecosystems in the world, covers

55   approximately one-fifth of land surface, and the typical steppe covers 10.5 % of the territory in

56   China (Wang *et al*, 2011). Precipitation is largely the only water source in semi-arid steppe

57   ecosystems, so the water consumed by plants is mainly from soil water after the redistribution of

58   precipitation in soil. For example, the deep-rooted shrub *Caragana microphylla* mainly utilizes

59 water from deep soil layer that is derived from winter snowfall and heavy precipitation; whereas
60 the shallow-rooted grass *Cleistogenes squarrosa* mainly utilizes surface soil water that is
61 dependent on summer precipitation (Yang *et al*., 2011). Mowing (for hay) is one of the main
62 utilization modes of semi-arid steppes. Mowing not only affects the redistribution of
63 precipitation in the soil by affecting the canopy structure of the community(Zhang *et al*.,2014;
64 Wang *et al*.,2015), but also affects the functional traits of plant roots(Zhang *et al*.,2014), and
65 these changes would inevitably affect the water sources of dominant plant species. Compared
66 with other ecosystems, the semi-arid steppe ecosystem is more sensitive to changes of water
67 resources (Lioubimtseva *et al*., 2005; Zhou *et al*., 2005), and more responsive to transient
68 fluctuations in resource availability (Zhang *et al*., 2014). Therefore, understanding the
69 mechanisms of plant water use is essential to steppe management by exploring how dominant
70 plants respond to instantaneous precipitation events and use available water resources in
71 enclosed and mowing conditions.

72   Traditional methods of studying plant water sources were difficult, such as root excavation
73 could determine the available water sources but the main water sources cannot be determined,
74 because the existence of roots does not mean that these roots are active in water absorption
75 (Flanagan et al. 1992). Comparatively, stable isotope technology has high sensitivity and
76 accuracy, and has wide applications in the study of water sources and water use efficiency of
77 plants in natural ecosystems (Yoder and Nowak 1999; Vandenschrick et al. 2002; Schwinning et
78 al. 2005; Nippert and Knapp 2007; Goldstein and Suding, 2014). In this study, we aimed to
79 explore how the three coexisting dominant species *Stipa grandis*, *Leymus chinensis* and *C.*
80 *squarrosa* in a typical steppe community respond to summer precipitation events in water use
81 under two grassland utilization modes (mowing and enclosed). The typical steppe, dominated by
82 *S. grandis*, *L.chinensis*, *S. krylovii*, and *Cleistogenes squarrosa* (Bai et al, 2008).We determined
83 the oxygen stable isotope ratios (δ^{18}O) of soil water and stem water of these three plants, and soil
84 water content before and after precipitation events in the mowing and enclosure plots. The
85 results would reveal the water use pattern and the competition relationship of plants in the typical
86 steppe, and have important theoretical significance for understanding the relationship between
87 plants and the environment under degradation in arid and semi-arid regions.

Materials and Methods

Study area

90   This experiment was conducted in the Grassland Ecosystem Research Station of the Inner
91 Mongolia University, located 40 km east of Xilinhot city in Central Inner Mongolia, China

92   (116°2′-116°30′ E, 44°48′-44°49′ N, 1101 m asl). The region experiences a temperate semi-arid

93   climate, with a mean annual temperature of 2.6 °C, the annual accumulated temperature of 2412

94   °C (>0 °C), and the average period of plant growth approximately 150 days; mean annual

95   precipitation is between 200 mm to 350 mm, 78 % of which falls between June to September,

96   and the annual evaporation is 1600-1800 mm (Wan *et al*., 2016; Bai *et al*., 2018). The major soil

97   type is a sandy loam chestnut soil, equivalent to Calcic-orthic Aridisol in the US soil taxonomy

98   classification system.

99   The vegetations in the study region are largely dominated by *S. grandis,* with *L. chinense*

100 and *C. squarrosa* as major species. The enclosure and mowing plots were started in 2011 to

101 study the effects of annual mowing on native steppe. Eight 20 m×30m experimental plots (four

102 enclosure and four mowing plots) were established with a distance of 5m between any two plots.

103 The mowing treatment was performed on August 20th of each year and begin from 2011.

Sample collection

105 Two precipitation events were recorded in July 2016, a light precipitation event of 10.8 mm

106 on 29 July and a medium precipitation event of 20.0 mm on 30 July. Samples were collected

107 separately on the day before these precipitation events (28th July) and on the first and fifth day

108 after precipitation (31st July and 4th August) from each experimental plot. Non-photosynthetic

109 tissues of plant from the interface between shoot and root systems were collected for the analysis

110 of oxygen stable isotope ratios (Thorburn *et al*., 1993). For each plant species, the non-

111 photosynthetic tissues from at least 20 individuals were collected in each plot and combined as

112 one replicate, enclosed in the screw-capped glass vial, immediately sealed with Parafilm, and

113 then stored at -20 °C for further stable oxygen isotope analysis.

114 The soil samples at the depth of 0-5 cm, 5-10 cm, 10-20 cm, 20-40 cm, 40-60 cm, 60-80 cm

115 and 80-100 cm in each plot were collected with a 5 cm diameter soil auger. One part of these soil

116 samples was immediately placed into a screw-capped glass vial, sealed with parafilm and then

117 stored at -20 °C for stable oxygen isotope analysis. The other part of the soil sample was placed

118 into an aluminum box and weighed to obtain the fresh weight, and then weighed after oven-

119 drying at 105 °C to get soil water content.

Water extraction and sample analysis

121 The water from the soil and plant samples was extracted with a cryogenic vacuum

122 distillation extraction system (Ehleringer *et al*., 2000). The water isotope analyzer (LGR 912-

123 0032, USA) was used to determine the $\delta^{18}O$ of the extracted water samples with a determination

124 precision of 0.1 ‰. Three kinds of laboratory working standard water were measured

125 additionally after every three samples against one of them as reference. The isotope ratio of

126 oxygen in water is expressed by the standard delta (δ) notation in parts per thousand (‰) as

127 follows:

128 $\qquad \delta^{18}O = (R_{sample} - R_{standard})/R_{standard} \times 1000$ (1)

129 where R_{sample} and $R_{standard}$ are the molar ratios of $^{18}O/^{16}O$ of the water sample and standard

130 water (V-SMOW) respectively.

Data analysis

132 Experimental data were analyzed using SPSS Version 19.0 (SPSS Inc., Chicago, USA).

133 Three-way analysis of variance (ANOVA) was conducted to test the effects of the sampling time

134 (ST), mowing (C) and soil depth (SD) on the soil water content and $\delta^{18}O$ with all of the factors

135 and their interactions being treated as fixed effects. The two-way ANOVA was also used to

136 examine the effects of the sampling time (ST) and mowing (C) on the $\delta^{18}O$ of plant water. In

137 addition, the differences in the $\delta^{18}O$ of plant water between the enclosure and mowing treatments

138 were tested using the independent sample t-test.

139 Potential water sources for the three plant species were divided into four layers of soil water,

140 which are 1) surface water layer (0-5 cm), 2) shallow water layer (5-10 cm), 3) middle water

141 layer (10-40 cm) and 4) deep water layer (40-100 cm). An IsoSource model (Philips & Gregg,

142 2003) was used to compare the isotope values of the water in the plant xylem and the isotope

143 values of various potential water sources, and thereby obtaining the feasible ranges of the

144 different water sources used by the three plant species at each sampling time (Phillips *et*

145 *al.*,2003). The source increment was defined as 2 %, and the mass balance tolerance was defined

146 as 0.01 ‰.

Results and analysis

Effects of summer precipitation on soil water content in mowing and enclosure steppe

149 Soil water content exhibited a very significant change before and after precipitation (Table

150 1, Fig. 1). As expected, the lowest soil water content appeared before precipitation and the

151 highest soil water content appeared on the first day after precipitation. The changes in the soil

152 water contents with the soil depths were different between the two experiment states. Under the

153 mowing and enclosure treatment, with the increasing soil depth the soil water content increased,

154 except the fifth day after the precipitation in enclosure grassland (Fig. 1).

Effects of summer precipitation on δ¹⁸O of soil water in mowing and enclosure steppe

Both mowing and the sampling time had no significant effects on the δ¹⁸O of soil water, but the interaction between the two factors and the soil depth had a significant effect on soil water δ¹⁸O (Table 2). Compared with the values under the enclosure treatment, the water δ¹⁸O for the deep layers under the mowing treatment showed a greater fluctuation with the increased sampling interval (Fig. 2). Under both treatments, with the soil depth increasing the δ¹⁸O of soil water decreased gradually with a reduction from the surface layer to the middle layer of -5.85 ‰, -7.31 ‰ and -8.44 ‰ respectively for the day before the precipitation and the first and fifth day after the precipitation under the mowing treatment, wihile a reduction of -4.86 ‰, -7.19 ‰ and -6.78 ‰ separately under the enclosed treatment for the three sampling time.

Effects of mowing and summer precipitation event on the water δ¹⁸O characteristics in plants

The mowing and sampling times had no significant effects on the water δ¹⁸O of any one of three plant species *(P>0.05)*, though the largest δ¹⁸O value of the three plant species appeared on the first day after precipitation (Fig. 3). Under the mowing treatment, the water δ¹⁸O value of the three plant species ranged from -8.891 ‰ to -4.934 ‰ for *L. chinensis*, -6.73 ‰ to -5.201 ‰ for *S. grandis* and from -2.202 ‰ to 2.062 ‰ for *C. squarrosa,* with the minimum values of water δ¹⁸O all occurring before the rainfall. Under the enclosure treatment, the minimum water δ¹⁸O value of the three plant species all occurred on the fifth day after precipitation, and their water δ¹⁸O ranged from -7.709 ‰ to -6.523 ‰ for *L. chinensis*, and -6.584 ‰ to -4.889 ‰ for *S. grandis* as well as -2.964 ‰ to 0.132 ‰ for *C. squarrosa* respectively. The isotope values of plant xylem water were similar to those of soil water, indicating that the water in this soil layer is utilized.

Effects of mowing and summer precipitation event on the water sources of the three dominant plant species

Mowing and precipitation events changed the water sources of the plants (Table 3, Fig. 4). As the estimated range of the proportion that a plant species took up from various soil layers are relatively wide and overlapping, we could not quantify the percentage of water taken up from a specific soil layer. A general pattern in the results (Table 3) was that *C. squarrosa* took up water majorly from top soil layer, *L. chinensis* took up relative more water from deep soil layer, and *S. grandis* took up water from the middle layer or from across various layers (Fig.4). Also, For *L. chinensis* and *S. grandis* in mowing grassland, the contribution rate of water form the upper soil

187 layer to the plant was separately 50.8% and 39.9% on the first day after precipitation, which was
188 higer than those of other soil layers. However, on the fifth day after precipitation, *L. chinensis*
189 tended to be stabilized to take up water from the shallow to deep soil layers with the ratio ranged
190 from 25.5% for middle soil layer and 30.2% for shallow soil layer, while *S. grandis* still took up
191 more water (40.7%) from the upper soil layer than other soil layers. In contrast, these two species
192 in enclosed grassland showed no sensitive change before and after the precipitation. *C.*
193 *squarrosa* used the water majorly from the top soil layer either under mowing or in enclosure,
194 and either before and after precipitation events.

Discussion

196 Soil water comes primarily from precipitation, and the precipitation amount and pattern
197 drives soil water dynamics (Wang *et al*., 2013). Combining the characteristics of soil water
198 isotopes with the analysis of soil water content can provide information on the soils role in
199 migration of rainwater. Our results show that the soil water content in the 0-40 cm soil layer
200 were no significant differences between mowed and enclosed grasslands, either before or after
201 precipitation, which may be related to vegetation cover. Mowing grassland had low vegetation
202 and litter cover, i.e., a high degree of soil exposure, thus may lead to a high evaporation of water
203 from the top soil layer. By contrast, the enclosed grassland has high vegetation and litter cover,
204 and thus the evaporation through soil surface was reduced (Ma *et al*., 2009). Our results also
205 show that with the increasing soil depth, the soil water content under the mowing treatment
206 gradually increased relative to that of the enclosure treatment. This might be related with dual
207 effects of mowing on water processes in soil profile: the first was a facilitation to water
208 infiltration during the precipitation event because of no litter coverage (Wang *et al*., 2011); and
209 second was a reduction in water uptake from deep soil layer due to less plant transpiration.

210 Evaporation would result in the enrichment of $\delta^{18}O$ in the surface soil water. Our results
211 show that with increasing soil depth, the evaporation decreased, and the isotopic abundance
212 decreased approximately exponentially with the depth until it reached a relatively constant
213 abundance, consistent with the results of Xu et al. (2012). There was no significant difference in
214 the precipitation infiltration or the fractionation degree of evaporation processes between the
215 mowing and enclosure treatments, but the $\delta^{18}O$ in the soil water at different soil depths under the
216 two treatments were both significantly affected by precipitation. After precipitation, the soil was
217 still affected by intense evaporation. In our study, in shallower soil, the heavy isotope in the soil
218 was enriched and the $\delta^{18}O$ increased, which agreed with previous studies (Tian *et al*., 2002; Jin *et*
219 *al*., 2015; Wang *et al*., 2009). Previous studies have shown that *L. chinensis* and *S. grandis*

220   respond differently to changes in the precipitation amount and pattern. Studies also show that
221   mowing reduces the density, height and biomass of *L. chinensis* (Guo *et al*., 2017). In this study,
222   the three dominant plant species *L. chinensis*, *S. grandis* and *C. squarrosa* exhibited a large
223   difference in water source before and after precipitation. Specifically, *L. chinensis* in mowing
224   grassland used the water majorly from the deep soil layer (40-100 cm) in dry soil before
225   precipitation, but substantial proportion of water uptake was from top soil layer on the first day
226   after precipitation, and the proportion declined gradually following the precipitation; while *L.*
227   *chinensis* in enclosed grassland took up water from various soil layers, did not exhibit a large
228   fluctuation. Similarly, *S. grandis* took up proportionally more water from the top soil layer after
229   than before precipitation in mowing grassland, while it showed no much difference in water
230   source before and after precipitation in enclosed grassland. Mowing had no significant effect on
231   the water source of *C. squarrosa*, which utilized soil water majorly from the top soil layer in all
232   cases. Our findings that *L. chinensis* tends to use more water from deep soil layer in comparison
233   to *C. squarrosa* and *S. grandis*, is supported by the findings of Yang et al. (2011). These results
234   also indicate that *L. chinensis* and *S. grandis* in mowing grassland are subject to more severe
235   water deficit in top soil layers before the precipitation (Fig. 1), thus more sensitive to
236   precipitation events than that from natural grassland. However, the rainfall intensity may impact
237   the distribution pattern of the soil water greatly and thus the plant water sources. In our study we
238   only studied the water source of the three species before and after the light and medium rain
239   event, the signatures of which may not adequately describe soil zones explored for water uptake.

240   The utilization of soil water by plants is closely related to the distribution of plant roots (Xu
241   and Li, 2006). *L. chinensis* is a rhizome grass, and its rhizomes are mainly distributed in the 5-10
242   cm soil layer, while the roots are mainly in the 0-30 cm soil layer; *S. grandis* is a tall bunchgrass,
243   and its roots are also concentrated in the 0-30 cm soil layer. *C. squarrosa* is a short bunchgrass,
244   with root system concentrated in the 0-10 cm soil layer(Chen *et al*.,2001; Ma *et al*.,1989; Zhu *et*
245   *al*., 2004). These differences in root morphology and distribution pattern among these three
246   species may partly explain the observed differences in their water uptake from different soil
247   layers. The difference between the *L. chinensis* and *S. grandis* root systems warrants further
248   studies to confirm the observed fact that *L. chinensis* took up proportionally more water than *S.*
249   *grandis* from deep soil layers.

250   **Conclusion**

251   In this study, we explored the water use sources of three coexisting dominant plant species
252   before and after precipitation events including *L. chinensis, S. grandis* and *C. squarrosa* growing

253 in both enclosed and mowing grassland in a typical steppe. We found that the soil moisture and
254 its $\delta^{18}O$ were not affected by mowing, and only the soil moisture changed significantly after the
255 precipitation. The three dominant plants showed divergent water sources with *C. squarrosa*
256 generally taking up water from top soil layer, *L. chinensis* taking up relative more water from
257 deep soil layer, and *S. grandis* just taking up water from the middle to deep soil layers. In
258 addition, *L. chinensis* and *S. grandis* in mowing grassland tended to take up more water from the
259 upper soil layers following precipitation events relative to those in the enclosed grassland,
260 indicating a more sensitive change of soil water sources for the two species in mowing than
261 enclosed grassland use. Our results have important theoretical values for understanding the water
262 competition among plants in fluctuating environment and under different land use in the typical
263 steppe.

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348

Figure 1

Characteristics of soil water content before and after precipitation under mowing and enclosure treatments

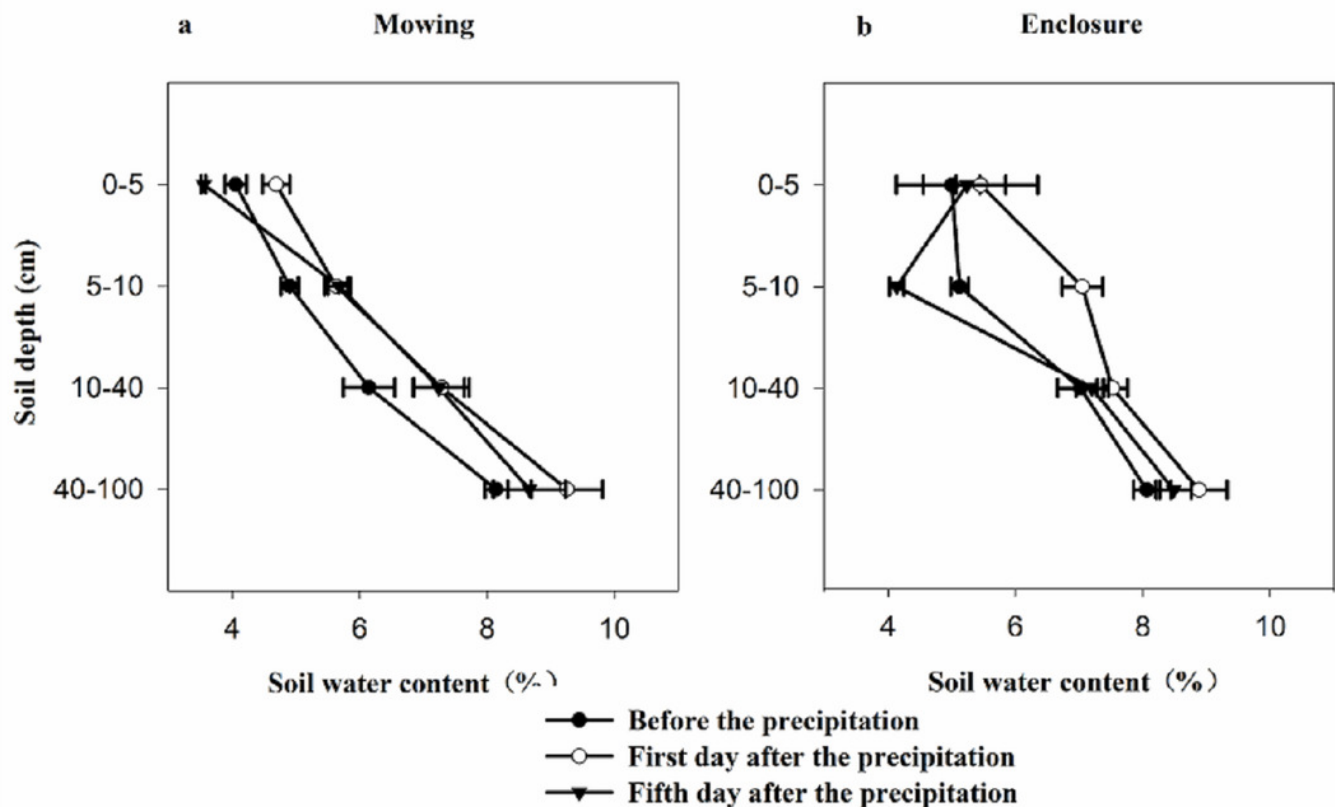



Figure 2

$\delta^{18}O$ characteristics of soil water before and after precipitation under mowing and enclosure treatments

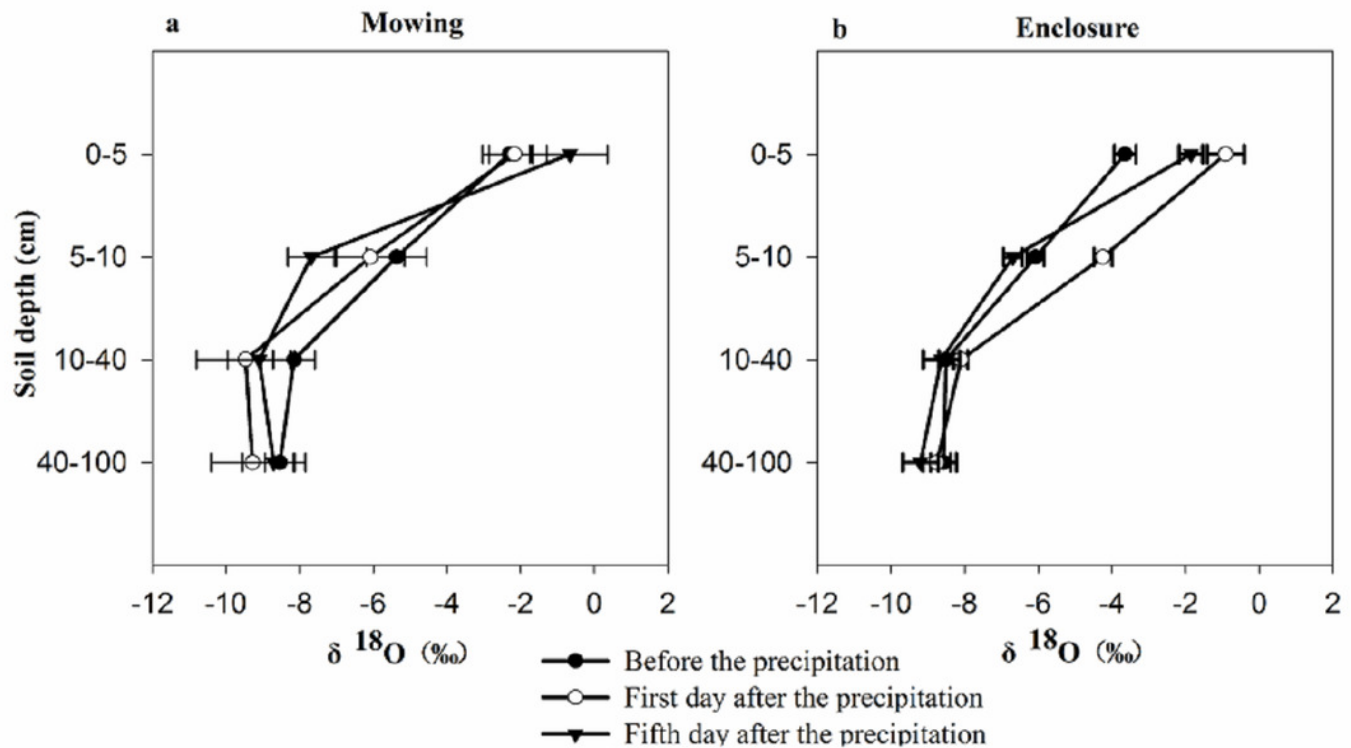



Figure 3

Characteristics of the water $\delta^{18}O$ in 3 plants before and after precipitation under mowing and enclosure treatments. bpt ,before the precipitation; 1datp, the first day after precipitation; 5datp, the fifth day after precipitation.

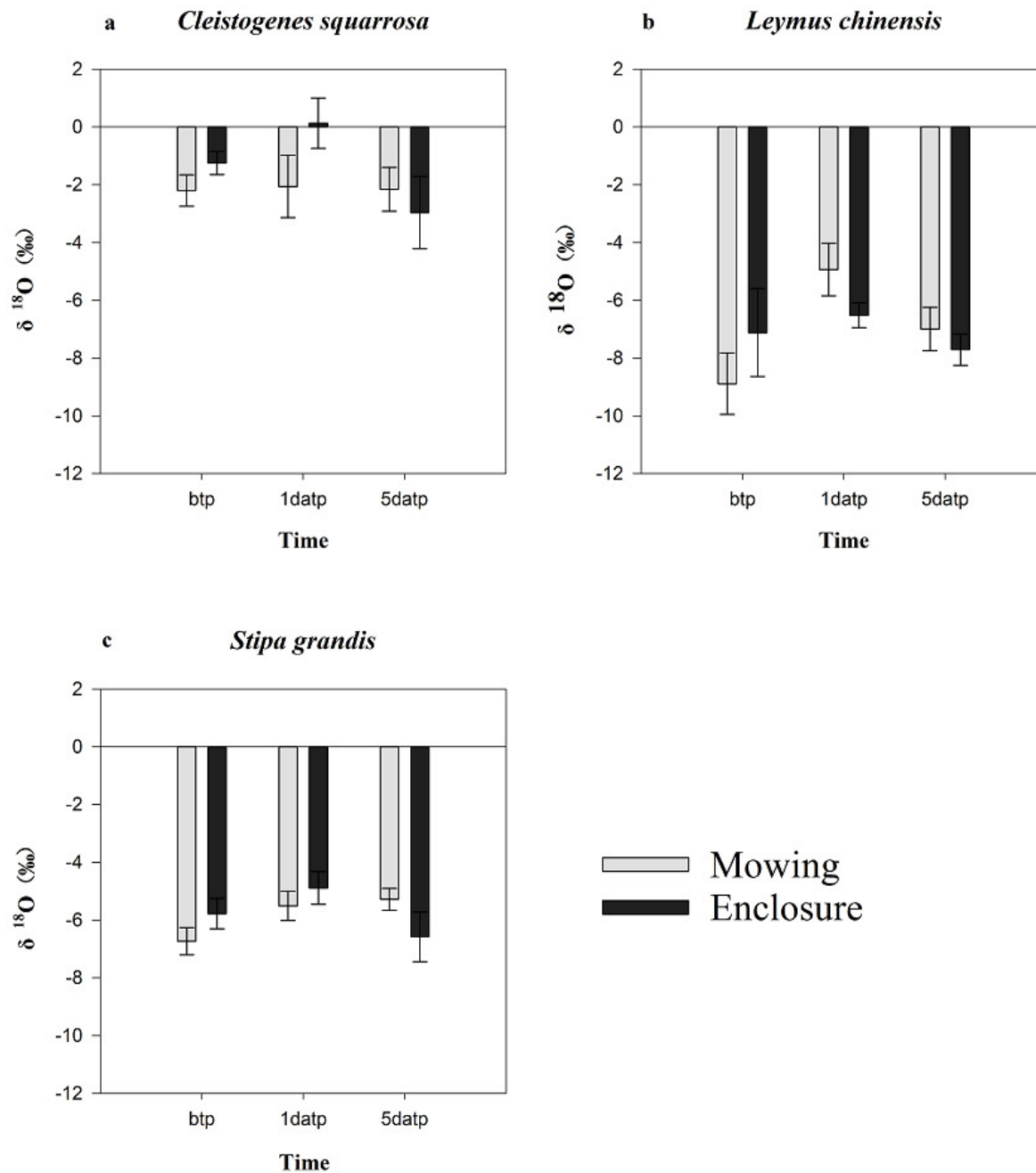
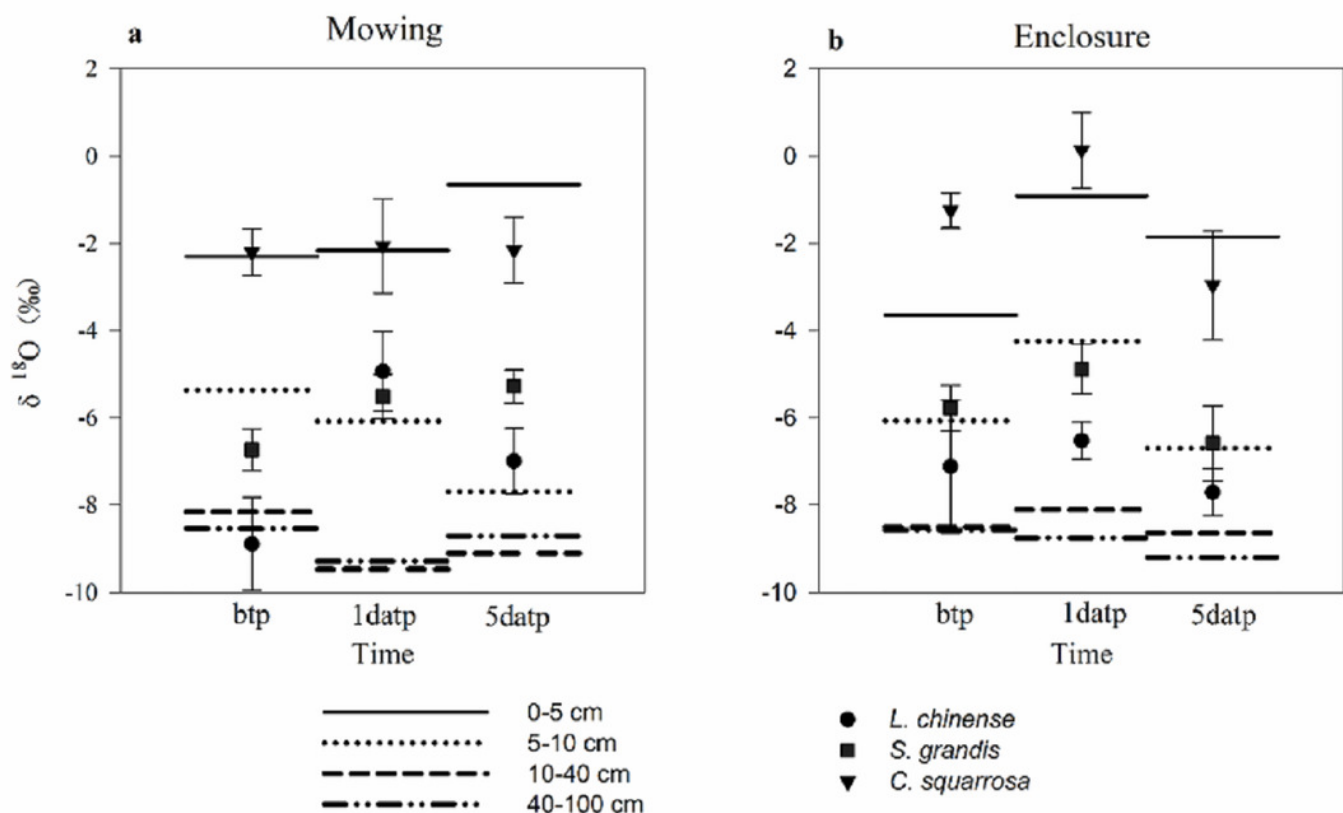



Figure 4

Soil water source of 3 plants under mowing and enclosure treatments before and after precipitation. bpt ,before the precipitation; 1datp, the first day after precipitation; 5datp, the fifth day after precipitation

ANOVA result for mowing (C), sampling time (ST) and soil depth (SD) on the soil water content

1 **Table 1** ANOVA result for mowing (C), sampling time (ST) and soil depth (SD) on the soil water content

Source	Type III Sum of Squares	df	Mean Square	F	*P*
C	0.000	1	0.000	0.99	0.323
ST	0.002	2	0.001	8.756	0.000
SD	0.028	6	0.005	46.242	0.000
C * ST	0.000	2	5.46E-05	0.534	0.588
C * SD	0.001	6	0.000	1.320	0.257
ST * SD	0.001	12	8.68E-05	0.849	0.601
C * ST * SD	0.001	12	8.23E-05	0.805	0.645
Error	0.009	84	0.000		
Total	0.684	126			
Corrected total	0.042	125			

ANOVA result for mowing (C), sampling time (ST) and soil depth (SD) on soil water $\delta^{18}O$

1   **Table 2**   ANOVA result for mowing (C), sampling time (ST) and soil depth (SD) on soil water $\delta^{18}O$

Source	Type III Sum of Squares	df	Mean Square	F	p
C	1.237	1	1.237	0.647	0.423
ST	2.371	2	1.185	0.620	0.540
SD	907.113	6	151.185	79.100	0.000
C * ST	15.850	2	7.925	4.146	0.018
C * SD	7.928	6	1.321	0.691	0.657
ST * SD	36.972	12	3.081	1.612	0.098
C * ST * SD	16.185	12	1.349	0.706	0.743
Error	214.067	112	1.911		
Total	9667.259	154			
Corrected total	1227.797	153			

Soil water utilization ratio of 3 plants in different soil layer under mowing and enclosure treatments before and after precipitation

1 **Table 3** Soil water utilization ratio of 3 plants in different soil layer under mowing and enclosure treatments before and after

2 precipitation

Sample date	Sample plot type	Plant species	The average contribution rate of each potential water source to plants (%)			
			0-5 cm	5-10 cm	10-40 cm	40-100 cm
Before precipitation	Mowing	*L. chinensis*	~	~	~	### [1)]
		S. grandis	14(0-20)	25.5(0-56)	32(0-66)	28.5(0-70)
		C. squarrosa	###	~	~	~
	Enclosure	*L. chinensis*	14.2(0-28)	29.6(2-58)	22(0-48)	34.2(20-48)
		S. grandis	36.5(12-56)	39(0-88)	20.9(0-44)	3.6(0-8)
		C. squarrosa	###	~	~	~
The first day after precipitation	Mowing	*L. chinensis*	50.8(34-62)	23.6(0-60)	14.4(0-38)	11.1(0-30)
		S. grandis	39.9(16-54)	29.9(0-82)	15.5(0-44)	14.6(0-46)
		C. squarrosa	###	~	~	~
	Enclosure	*L. chinensis*	13.2(0-28)	21.7(0-48)	33.7(0-78)	31.4(0-68)
		S. grandis	27.1(0-48)	35.9(0-84)	19.2(0-50)	17.8(0-48)
		C. squarrosa	###	~	~	~
The fifth day after precipitation	Mowing	*L. chinensis*	18.7(10-24)	30.2(0-90)	25.5(0-70)	25.6(0-70)
		S. grandis	40.7(36-44)	21.4(0-54)	18.4(0-48)	19.4(0-54)
		C. squarrosa	80.9(80-82)	7.1(0-14)	7.7(0-16)	4.3(0-10)
	Enclosure	*L. chinensis*	9(0-20)	25.8(0-58)	33.2(0-82)	32(0-76)
		S. grandis	22.6(4-34)	32.8(0-92)	23(0-64)	21.5(0-60)
		C. squarrosa	81.6(78-84)	8.4(0-20)	5.1(0-12)	4.9(0-12)

3 Note: The symbol "###" refers to the soil layer where major water source is from for the examined species, as the $\delta^{18}O$ value of plant stem

4 water is higher than the soil water in top soil layer or lower than bottom soil layer. The symbol "~" refers to the soil layer where no water

5 source is from for the examined species.