Dynamic of aboveground biomass and soil moisture as affected by short-term grazing exclusion on eastern alpine meadow of Qinghai-Tibet plateau, China

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ABSTRACT

Short-term grazing exclusion has large impacts on grassland vegetation and nutrition. In order to study the effects of the short-term rest on aboveground biomass, forage quality, and soil moisture on alpine pasture of the Qinghai-Tibet plateau, cages were used to exclude grazing from July to October on summer pasture used by three typical farms with different stocking rates. The results showed that, within the same month during the forage growth period, the dry weights of the edible forage in the cages were significantly higher than that out of the cages ($P < 0.05$) under heavy grazing pressure (from 2.47 to 2.48 animal unit equivalent AUE ha^{-1}). Within the same soil depth, soil moisture was significantly different in, and out of, the cages ($P < 0.05$) and it decreased with depth. The crude protein content for forages in cages was significantly higher than that out of the cages for the farm with a heavy stocking rate and the neutral detergent fiber was significantly lower. This shows that short-term rest periods could effectively increase dry weight and crude protein content of the edible forage for farms with heavy stocking rates. This short-term rest management strategy is recommended for farms with a heavy stocking rate.

Key words: Biomass of edible forage, cage, forage quality, ground coverage, soil moisture content.

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INTRODUCTION

Tibetan grasslands constitute one of the most important grazing ecosystems in the world. Distributed widely across the high plains and mountains of the Tibetan plateau, these grasslands encompass the source areas of many major Asian rivers. Around 40 percent of the world's population depends on, or is influenced by, these rivers (Foggin, 2008). Rangelands in this area, although sparsely populated and contributing little to China' overall economic condition, play an important environmental role throughout Asia by affecting temperatures and the quality of water and air (Harris, 2010). The alpine pasture of the Qinghai-Tibet plateau (QTP) is regarded as the most unique alpine pasture ecosystem in the world due to its coverage (2.57 million km^2, up to 25% of total area of China) and high elevation (4000 m on average) (Mu and Wu, 2005; Cao et al., 2011; Li et al., 2012). It is also the feed base for the grassland animal husbandry in China (Zhou et al., 2005). Therefore, it plays an essential role in the ecology and animal production of China as well as the environmental role throughout Asia (Harris, 2010).

Alpine meadow is the main pasture type in the QTP, covering 46.67% of the total area (Dong et al., 2007a). *Kobresia* Willd., *Elymus dahuricus* Turcz. ex Griseb., and *Polygonum viviparum* L. are dominant species. Two seasonal pastures are used by the local farms, with livestock on the summer-autumn pasture from July to October and on the winter-spring pasture for the remainder of the year. In the past few years, the QTP has suffered from severe degradation, which leads to a reduction in herbage yield and deterioration of the ecological environment (Du et al., 2004). At present, the degraded area is up to 0.45×10^8 ha, approximately one-third of the total QTP area (Zhou et al., 2005). Studies have been conducted to find causes of the degradation and mitigation methods (Wang et al., 2006a; Wu et al., 2010; 2013). Besides unsustainable grazing management, global climate change, excessive herbivory, soil disturbance from small mammals, and historical-cultural impediments, overgrazing is regarded as one of the major causes of degradation (Zhou et al., 2006; Harris, 2010; Wu et al., 2014). Enclosure is widely accepted as a valuable tool to restore degraded grasslands of QTP (Ma et al., 2002; Dong et al., 2007b; Shang et al., 2013). It could improve the net primary production and modify species composition due to the selective grazing behavior of animals (Zheng et al., 2005; Wu et al., 2013). Other benefits, especially the benefits of long-term enclosure, were widely reported (Dong et al., 2007b; Mayer et al., 2009; Wu et al., 2009b; Wu et al., 2010; 2013; Fernández-Lugo et al., 2013; Shang

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et al., 2013). However, grazing is the most fundamental grassland utilization, long-term grazing exclusion might be a kind of resources waste for animal husbandry production and it had severe negative effects on the vegetation restoration and feed nutrients (Cuevas and Le Quesne, 2005; Wu et al., 2009a). In addition, it resulted in the increasing of the aboveground biomass of the poisonous locoweeds (Wu et al., 2014) and had the similar effects on species composition, ground cover, and biomass as those resulting from moderate grazing (Courtois et al., 2004).

Effects of grazing exclusion on plant species richness and phytomass accumulation varied across a regional productivity gradient and the duration of exclusion (Schultz et al., 2011). Short-term grazing exclusion may favor the improvements in species richness and biomass accumulation (Mayer et al., 2009). By now, there is no report on the short-term enclosure (within one year) in eastern alpine meadows of the QTP.

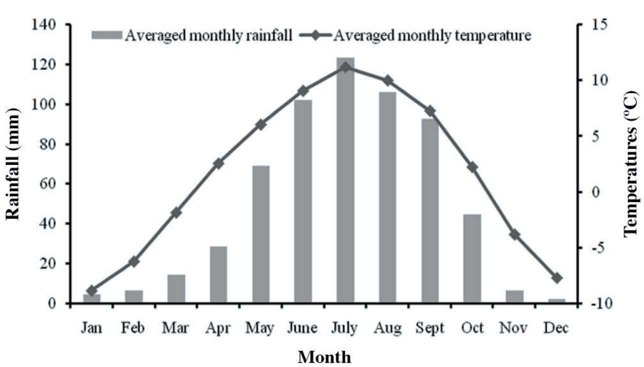
The objective of this 2 yr study was to investigate the effects of short-term grazing exclusion (from July to October) on forage yield and quality and soil moisture in eastern alpine meadows of the QTP by determining the aboveground biomass, forage nutrition and soil moisture between grazed and un-grazed plots for three typical farms with different grazing intensities.

MATERIALS AND METHODS

The experiment was carried out in Ouqiang village (102°29' E, 34°30' N; 3300 to 3650 m a.s.l.), Maqu county of the Gannan Tibetan Autonomous Prefecture, Gansu province, China, located in the eastern part of the Qinghai-Tibet plateau (QTP). Figure 1 shows annual precipitation and temperature from 1969 to 2012 (data provided by the Animal Husbandry Division Office of Maqu County).

The experimental area has alpine meadow soil, which is primarily Mat-Cryic Cambisols (Sun et al., 2015), and the vegetation type was alpine meadow dominated by families *Gramineae* and *Cyperaceae* (Wu et al., 2010), and other species including the family *Ranunculaceae*, *Polygonaceae*, *Saxifragaceae*, *Asteraceae*, *Scrophulariaceae*, *Gentianaceae*, and *Fabaceae* (Ma et al., 2013). In 2011 and 2012, the precipitation in the growing season (from May to October) was 459 and 472 mm, respectively. The average temperature during the growing season was 8.2 °C for 2 yr.

Figure 1. Averaged monthly temperature and precipitation from 1969 to 2012 on alpine pasture of the Qinghai-Tibet plateau.



At the end of June 2011, three farms with different animal load (from low to high) and same precipitation and temperature were selected as the experimental farms. On each farm, three 2.25 m^2 (1.5 × 1.5 m) cages were established on the summer pasture along the slope (stands for different biomass levels) to exclude grazing from July to October in 2011 and 2012 (IC treatment) for comparison with each grazed pasture out of the cages nearby (OC treatment). The IC and OC experiments had three replicates. Then the averaged values of three IC replicates were regarded as the value of IC, and the same as the OC treatment. The summer pasture type, area, animal unit and animal load of pastures of the three farms are listed in Table 1 and are referred to as pasture 1, 2, and 3. The animal unit equivalent (AUE) was calculated on each pasture using the formula of $AUE = (W_{initial})^{0.75}(W_{ref}^{0.75})^{-1}$, where $W_{initial}$ (kg) is the averaged live weight of different animal group at the beginning of the experiment, W_{ref} (kg) is the 454 kg reference live weight for an animal unit (Schlegel et al., 2000; Sun et al., 2015).

In the middle of July, August, September and October, 2011 and 2012, on the summer pasture of the three farms, richness index was determined by counting the total plant species numbers using a 0.25 m^2 (0.5 × 0.5 m) pin quadrat both in and out of the cages. And the coverage of each species was calculated using the formula:

Coverage of species A = (Hits of species A/Total points) × 100

Plant community in the experimental area was divided into four functional groups. They were grass species group (GG), sedge species group (SG), forbs species group, not including noxious species (FG), and noxious species group (NG), respectively. The coverage of each functional group was determined in each quadrat. Within each functional group, the list of all families, genus, and their edibility was shown in Table 2 (edible plants mean those plants that can be eaten by animals while inedible plants mean noxious plants).

After the pasture monitoring ended, the aboveground vegetation was cut, divided into edible and inedible forage, put each part in a big paper bag, and determined the fresh weight separately in the field using the BS 510 balance (capacity is 300 g and can be rounded to two decimals) (Du et al., 2013). Samples were then taken to the lab to determine dry weight (DW) of edible and inedible plants, and chemical composition of edible plants.

The water content in the forage was measured daily using the oven-dried method (Soil Science Society of China, 1999) while samples were dried at room temperature (about 21 °C).

Table 1. Information on the three typical pastures.

Pasture	Pasture type	Area	Sheep unit 2011	Sheep unit 2012	Animal load 2011	Animal load 2012
		ha	AUE		AUE ha^{-1}	
1	Alpine meadow	157	388.75	389.90	2.47	2.48
2	Alpine meadow	213	145.18	121.34	0.68	0.57
3	Alpine meadow	667	231.68	186.65	0.35	0.28

The DW was determined after 5 d when forage water content reached 30% (Du et al., 2013). The percentage of edible forage was calculated using the formula:

$$EDW\,\% = \left(\frac{EDW}{EDW + IDW}\right) \times 100$$

where the *EDW* means dry weight of the edible forage and *IDW* means dry weight of the inedible forage. For IC and OC treatment on each farm's pasture, a 10 g sample of edible forage was collected from each quadrat and three samples from the same treatment were then evenly mixed and pulverized to determine chemical composition of forages.

Soil samples were taken on pastures of all three farms, both in and out of the cages, using a drill (auger) and aluminum weighing tins. The 0 to 10, 10 to 20, 20 to 30, 30 to 40, and 40 to 60 cm depths were sampled in triplicate and three samples were mixed evenly and divided into three aluminum weighing tins. The fresh weight were then determined in the field using the BS 510 balance and the samples were oven-dried at 105 °C for 8 h and cooled in a desiccators for 30 min and weighed (Soil Science Society of China, 1999; Liu et al., 2006).

The Kjeldahl N method (Guo and Meng, 2006) was used to determine crude protein (CP) in the edible forage samples, and acid detergent fiber (ADF) and neutral detergent fiber (NDF) content were determined using the Van Soest method (Xue and Meng, 2006).

For each pasture, data were analyzed using paired-sample T-test to compare the differences of individual parameters within and outside the exclusion cages in the same months between 2011 and 2012. The statistical package used for the analysis was SPSS version 19.0 (IBM Corp., Armonk, New York, USA). The data analyzed included DW of edible and inedible forage, percentage of edible forage, vegetation coverage, forage CP, ADF, and NDF, and soil moisture content. If significant differences were detected, a paired-sample T-test (within and outside the cage) was undertaken to compare differences within years. Otherwise, data of same months and treatments were averaged and analyzed.

RESULTS

For all three pastures, nonsignificant differences were detected in DW of edible and inedible forage, percentage of edible forage, vegetation coverage, and CP, ADF, and NDF content for the same months and same treatments between 2011 and 2012. Therefore, data from the 2 yr were averaged.

Dry weight of edible (EDW) and inedible (IDW) forage

For the averaged EDW, it varied among the three pastures for IC and OC treatments from July to October, but within the same pasture, it remained at a similar level between IC and OC treatments in July (Table 3). This index continually increased in pasture 3, but for pastures 1 and 2, it increased from July to September, and then decreased from September to October. For the three pastures, EDW differences between IC and OC treatments (IC - OC) were different in July: for pasture 1, it was positive, but negative for the other two. From August to October, EDW in the cages (ICEDW) for all three pastures were significantly or insignificantly higher than that of EDW out of the cages (OCEDW) (columns 3 and 4 in Table 3). From September to October, ICEDW and

Table 2. Families and genus within each plant functional group and their edibility.

Family	Genus	Edibility	Functional group	Family	Genus	Edibility	Functional group
Gramineae	*Festuca*	E	GG	*Leguminosae*	*Gueldenstaedtia*	I	NG
Gramineae	*Stipa*	E	GG	*Compositae*	*Leontopodium*	I	NG
Gramineae	*Deschampsia*	E	GG	*Compositae*	*Ligularia*	I	NG
Gramineae	*Elymus*	E	GG	*Compositae*	*Anaphalis*	I	NG
Gramineae	*Holcus*	E	GG	*Euphorbiaceae*	*Euphorbia*	I	NG
Gramineae	*Poa*	E	GG	*Saxifragaceae*	*Parnassia*	I	NG
Gramineae	*Agrostis*	E	GG	*Violaceae*	*Viola*	I	NG
Gramineae	*Koeleria*	E	GG	*Polygonaceae*	*Rheum*	I	NG
Cyperaceae	*Scirpus*	E	SG	*Gentianaceae*	*Gentianopsis*	I	NG
Cyperaceae	*Kobresia*	E	SG	*Gentianaceae*	*Lomatogonium*	I	NG
Cyperaceae	*Carex*	E	SG	*Gentianaceae*	*Gentiana*	I	NG
Polygonaceae	*Polygonum*	E	FG	*Geraniaceae*	*Geranium*	I	NG
Rosaceae	*Alchemilla*	E	FG	*Ranunculaceae*	*Halerpestes*	I	NG
Rosaceae	*Potentilla*	E	FG	*Ranunculaceae*	*Trollius*	I	NG
Compositae	*Taraxacum*	E	FG	*Ranunculaceae*	*Ranunculus*	I	NG
Compositae	*Cremanthodium*	E	FG	*Ranunculaceae*	*Thalictrum*	I	NG
Compositae	*Saussurea*	E	FG	*Ranunculaceae*	*Aconitum*	I	NG
Compositae	*Ajania*	E	FG	*Ranunculaceae*	*Anemone*	I	NG
Compositae	*Artemisia*	E	FG	*Equisetaceae*	*Equisetum*	I	NG
Liliaceae	*Allium*	E	FG	*Umbelliferae*	*Chamaesium*	I	NG
Valerianaceae	*Nardostachys*	I	NG	*Umbelliferae*	*Carum*	I	NG
Plantaginaceae	*Plantago*	I	NG	*Umbelliferae*	*Pleurospermum*	I	NG
Labiatae	*Lamiophlomis*	I	NG	*Scrophulariaceae*	*Lancea*	I	NG
Labiatae	*Ajuga*	I	NG	*Scrophulariaceae*	*Euphrasia*	I	NG
Leguminosae	*Astragalus*	I	NG	*Scrophulariaceae*	*Pedicularis*	I	NG
Leguminosae	*Oxytropis*	I	NG	*Scrophulariaceae*	*Lagotis*	I	NG

E: Edible, I: inedible, GG: grass species group, SG: sedge species group, FG: forbs species group, and NG: noxious species group.

Table 3. Dry weight of the edible forage in (IC) and out (OC) of the cages on three summer pastures.

Pasture	Month	EDW IC	EDW OC	P value	Increasing rate
		g m^{-2}			%
1	July	15.77 ± 1.37a	15.34 ± 1.65a	0.88	2.85
	Aug	232.42 ± 13.09a	78.41 ± 13.50b	0.01	196.41
	Sept	383.57 ± 23.20a	104.02 ± 8.73b	0.01	268.74
	Oct	222.97 ± 11.24a	117.51 ± 10.24b	0.04	89.75
2	July	104.40 ± 14.95a	119.14 ± 10.15a	0.39	-12.37
	Aug	297.48 ± 9.91a	227.92 ± 14.62a	0.08	30.52
	Sept	355.21 ± 23.28a	275.51 ± 12.94a	0.13	28.93
	Oct	310.47 ± 10.00a	245.18 ± 14.12a	0.11	26.63
3	July	61.32 ± 4.31a	64.70 ± 0.80a	0.49	-5.23
	Aug	266.50 ± 13.59a	164.68 ± 9.62b	0.03	61.83
	Sept	326.94 ± 14.17a	238.71 ± 20.35b	0.02	36.96
	Oct	352.78 ± 21.26a	314.93 ± 9.80a	0.20	12.02

EDW: Averaged dry weight of the edible forage for 2011 and 2012 in the cage (IC) and out of the cage (OC) treatments, respectively.
All EDW values are means ± SD. For the same pasture and same month, different letters between OC and IC represent significant differences at P < 0.05.
Increasing rate (%) = [(IC – OC)/OC)] × 100

OCEDW both peaked. Within the same month, the increasing rate of ICEDW differed from -12.37% (pasture 2 in July) to 268.74% (pasture 1 in September) and with a faster increase found on pasture 1.

The paired samples T-test showed that nonsignificant differences existed between IC and OC of pasture 2 in every month. For pasture 1, ICEDW was significantly higher than OCEDW ($P < 0.05$) except in July, and significant differences were also found in August and September ($P < 0.05$) for pasture 3.

The averaged IDW of 2 yr increased from July to September for three pastures, the maximum value (53.41 ± 4.14 g) was found on pasture 2 in September out of the cage. Non significant differences existed between IC and OC treatments from July to October.

Percentage of edible forage and richness index

The averaged percentages of edible forage for the OC treatment decreased gradually from July to October, except in pasture 2 in September and October, and the averaged percentages of edible forage for IC treatment also decreased from July to October for pastures 1 and 3 (Figure 2). For the same pasture, the percentage of edible forage for IC was equal or a little higher than that of OC within the same month ($P > 0.05$), and the biggest difference between IC and OC was found in pasture 1.

Richness index varied from 13.67 ± 0.44 to 22.67 ± 0.93 for IC treatment and for OC, they varied from 12.17 ± 0.44 to 20.33 ± 0.83 (Figure 3). T-test showed that there was nonsignificant difference between IC and OC treatment on all three pastures in 2011 and 2012 except for the IC value in September on pasture 3.

Vegetation coverage

For three pastures, nonsignificant differences were found for the coverage of GG between IC and OC treatment in

Figure 2. Percentage of the edible forage for in cages (IC) and out of cages (OC) treatments on three pastures. All data were the average of 2011 and 2012.

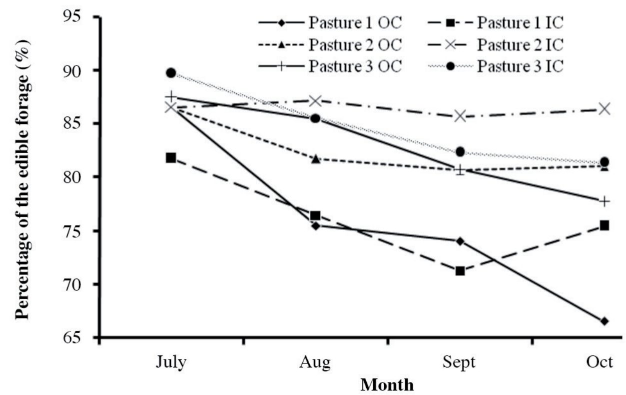
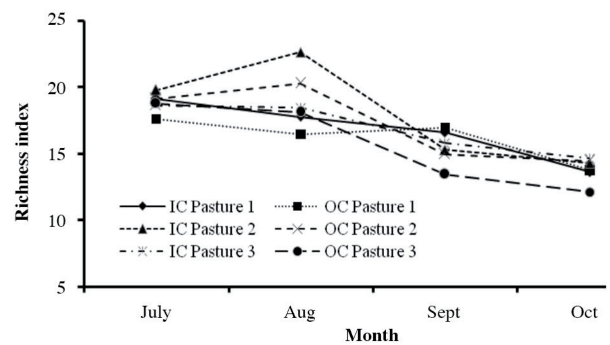


Figure 3. Richness index in cages (IC) and out of cages (OC) for the three pastures. All data were the average of 2011 and 2012.

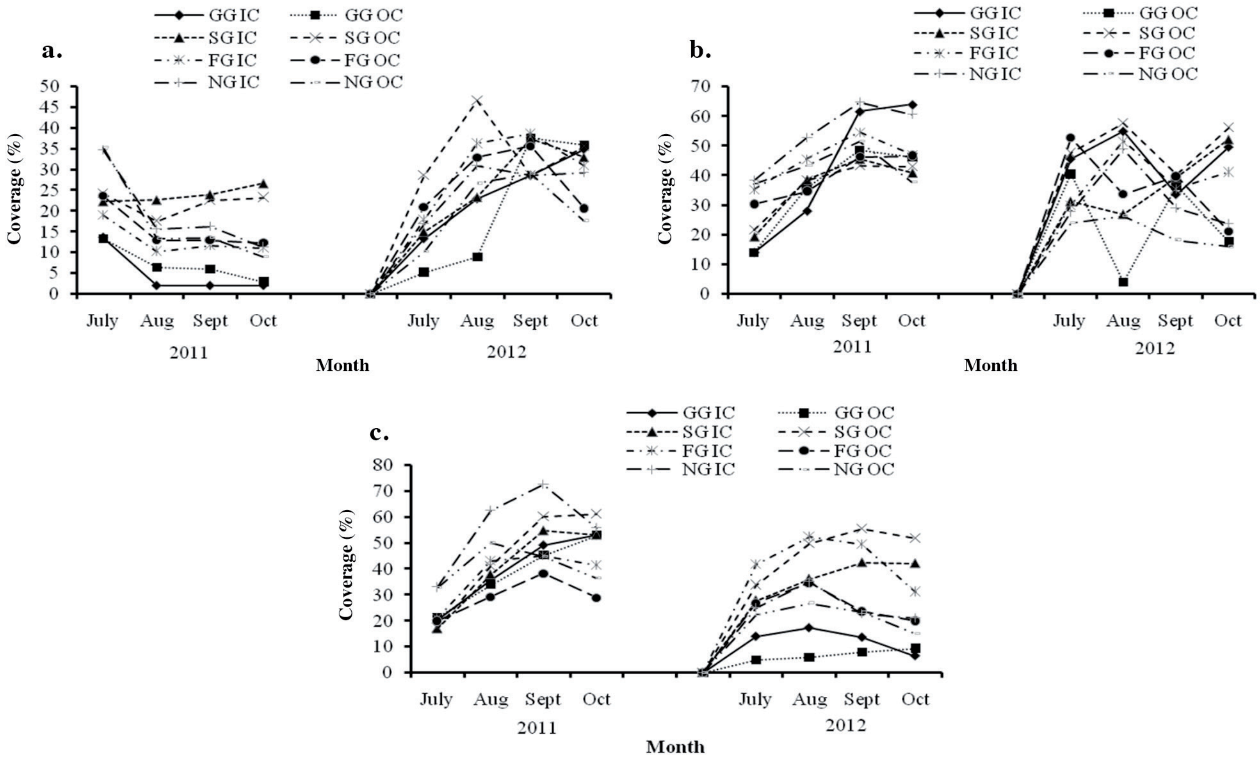


2011, while the GG coverage in IC was significantly high in July and August on pasture 3 in 2012. For three pastures nonsignificant differences were detected between IC and OC treatment in 2011 for SG; while in 2012, SG coverage of IC was significantly lower than the coverage of OC in August on pasture 1, and the same situation occurred in July and August on pasture 2. On pasture 2, the coverage of FG in IC was significantly high in July 2011, while the result was the opposite in 2012, the FG coverage in IC was significantly low in July but significantly high in August. For inedible or noxious plants, nonsignificant differences existed between IC and OC treatment in 2011 on three pastures, but in 2012, the coverage in IC was significantly high in August on pasture 1 and also the same situation occurred in October on pasture 2 (Figure 4).

Crude protein (CP), acid detergent fiber (ADF), and neutral detergent fiber (NDF) content

From July to October, mean values of monthly CP content on the three pastures declined both in IC and OC treatments. Except for pasture 1, the highest value (10.91%) for OC treatment was in August (Table 4). For the same pasture, within the same month, differences between IC and OC treatments were significant ($P < 0.05$). For pasture 1, mean values of OC treatment were significantly higher than that of IC treatment in July and August, but the situation was the

Figure 4. Coverage of the vegetation for in cages (IC) and out of cages (OC) treatments on three pastures in 2011 and 2012.



(a) Vegetation coverage on pasture 1, (b) vegetation coverage on pasture 2, and (c) vegetation coverage on pasture 3.
GG: Grass species group, SG: sedge species group, FG: forbs species group, NG: noxious species group.

opposite in September and October. Values of IC treatment for pasture 2 were significantly higher than that of OC treatment in July, August and September. For pasture 3, OC treatment values were significantly higher than that of IC treatment from August to October, but in July, IC treatment value was significantly higher.

For ADF content from July to October, the averaged ADF content increased (Table 4). Mean values ranged from 26.59% (July IC value for pasture 1) to 50.26% (October OC value for pasture 2). The OC values for pastures 2 and 3 were significantly higher than that of the corresponding IC value except for pasture 3 in July where values were the same. For pasture 1, ADF contents for IC treatment were significantly higher in August and September while they were significantly lower in July and October ($P < 0.05$).

Mean values of NDF content of 2 yr varied from 37.75% (IC and OC treatments in July for pasture 1) to 67.85% (IC treatment in October for pasture 2). Within the same month, significant differences were detected between IC and OC treatments except for pastures 1 and 3 in July (Table 4). For

Table 4. The crude protein (CP), acid detergent fiber (ADF), and neutral detergent fiber (NDF) content in the edible forage for the three pastures.

		CP		ADF		NDF	
Pasture	Month	IC	OC	IC	OC	IC	OC
		%					
1	July	10.43 ± 0.02b	10.86 ± 0.05a	26.59 ± 0.03b	34.50 ± 0.05a	37.75 ± 0.05a	37.75 ± 0.04a
	Aug	9.71 ± 0.08b	10.91 ± 0.02a	41.59 ± 0.03a	34.01 ± 0.05b	57.70 ± 0.03a	56.31 ± 0.04b
	Sept	9.63 ± 0.13a	8.54 ± 0.04b	41.35 ± 0.04a	38.54 ± 0.03b	55.68 ± 0.05b	56.45 ± 0.06a
	Oct	8.53 ± 0.16a	6.65 ± 0.06b	41.15 ± 0.03a	41.56 ± 0.04a	54.85 ± 0.04b	56.78 ± 0.02a
2	July	8.63 ± 0.08a	7.63 ± 0.03b	35.46 ± 0.05b	37.46 ± 0.06a	56.48 ± 0.04b	58.46 ± 0.06a
	Aug	7.65 ± 0.05a	6.51 ± 0.06b	37.45 ± 0.06b	39.45 ± 0.04a	59.46 ± 0.04b	62.15 ± 0.05a
	Sept	6.36 ± 0.05a	5.85 ± 0.05b	43.73 ± 0.08b	45.12 ± 0.08a	65.13 ± 0.03b	66.27 ± 0.03a
	Oct	5.64 ± 0.06b	6.25 ± 0.05a	48.75 ± 0.05b	50.26 ± 0.02a	67.85 ± 0.05a	66.25 ± 0.02b
3	July	10.27 ± 0.04a	10.07 ± 0.02b	30.65 ± 0.02a	30.65 ± 0.03a	57.22 ± 0.03a	57.22 ± 0.03a
	Aug	5.85 ± 0.05b	8.54 ± 0.03a	37.84 ± 0.04b	40.25 ± 0.05a	59.64 ± 0.05a	57.98 ± 0.01b
	Sept	4.83 ± 0.04b	7.15 ± 0.06a	43.55 ± 0.02b	47.08 ± 0.03a	61.97 ± 0.05a	58.03 ± 0.05b
	Oct	4.56 ± 0.02b	6.95 ± 0.02a	44.31 ± 0.04b	50.16 ± 0.02a	66.45 ± 0.02a	59.28 ± 0.01b

IC: In the cage, OC: out of the cage.
All data are the average of 2011 and 2012. Within the same pasture, same month, and same parameter, different letters between the IC and OC indicate significant differences at $P < 0.05$.

pasture 1, IC values were significantly higher in August but lower in September and October. The IC values from pasture 2 were significantly lower than that of OC values in July, August and September but it was significantly higher in October. From August to October, NDF of IC from pasture 3 was significantly higher than that of OC.

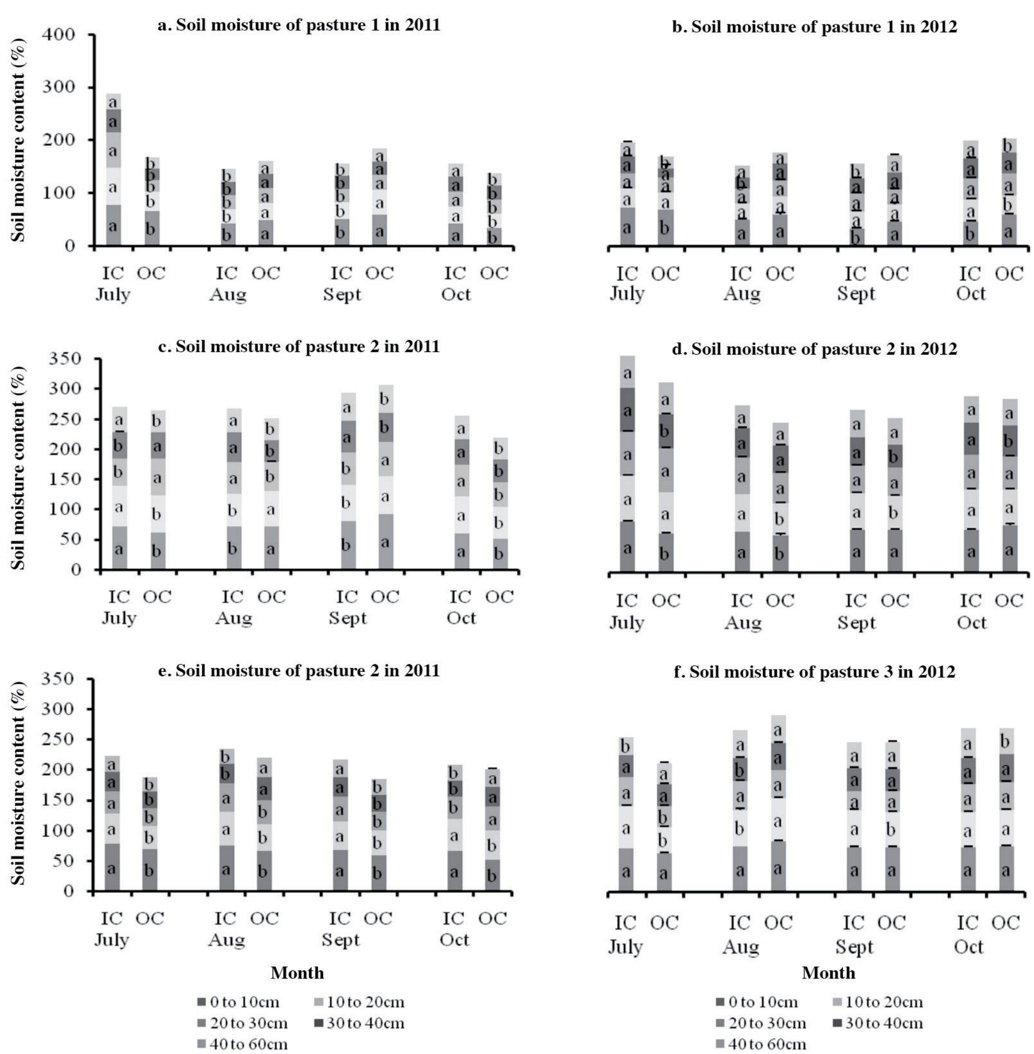
Soil moisture content

For all three pastures, significant differences (P < 0.05) in soil moisture were detected for the same months and same treatments between 2011 and 2012. And within the same year, significant differences (P < 0.05) also existed between IC and OC treatments in most soil depths (Figure 5). Within the 4-mo, soil moisture changed very little at 40-60 cm, but it changed dramatically at 0-10 cm and 10-20 cm. Soil moisture decreased with an increase in soil depth for IC and OC treatments. For pasture 1, soil moisture of IC treatment in 2011 was significantly lower compared with OC values in the same depth in August and September, but it was opposite in July and October (Figure 5a). At 0 to 10 cm and 10 to 20 cm, soil moisture varied for IC and OC treatments.

DISCUSSION

Previous studies have indicated that animal load influences characteristics of grassland vegetation (Liu et al., 2002). Grazing is one of the most important ways to manage the terrestrial ecosystem and that it would directly affect the health of global natural environment and human society (Hou and Yang, 2006). Fencing is one of the main methods to handle severe degradation in QTP (Miao, 2012). However, long-term grazing exclusion could decrease plant diversity and alter ecological succession (Yuan et al., 2004; Ren et al., 2008). The effect of short-term rest on the ecosystem remains unsure in QTP. This 2-yr experiment was designed to study the effects of short-term grazing exclusion on the productivity and quality of aboveground biomass and soil moisture on summer pastures under various stocking rates

Figure 5. Soil moisture content in cages (IC) and out of cages (OC) for three pastures in 2011 and 2012.



For each figure, different letters between the soil moisture content at the same depths within the same months in (IC) and out of (OC) the cages indicate significant differences at P < 0.05.

and focused on the edible forage, because it is the essential component for the livestock. According to the heavy animal load (6.07 head ha^{-1}) reported by Zhao et al. (2000), pasture 1 in this experiment had a very high animal load (2.47-2.48 animal unit equivalent [AUE] ha^{-1}), and the stocking rate of the other two pastures was low, especially pasture 3. The results demonstrated that short-term rest may be one of the most efficient ways to increase productivity of edible forage in QTP, especially on summer pastures with a heavy stocking rate, such as that of pasture 1 (Tables 1 and 3).

The percentage of edible forage could be used to evaluate health and productivity of a pasture (Zhao et al., 2011). For the three pastures, the percentage of edible forage in OC treatments all decreased from July to October, with pasture 1 having the largest decrease. Mainly because the livestock continually graze the edible forage but not poisonous weeds (Zhao et al., 2000). The percentage of edible forage for IC treatments slightly decreased due to the common growth of edible and inedible forage. The percentage of edible forage in this study indicated that the biomass of vegetation composition in this region was relatively stable. Within the same month and for the same pasture, the percentage of edible forage in IC treatments (grazing excluded) was higher than that of the OC treatments (with grazing), and the difference was bigger with a heavier stocking rate, such as on pasture 1 (Figure 2). This demonstrated that short-term rest maybe useful for maintaining health and productivity of the pasture on QTP, especially under high grazing pressure.

Richness index can be used to evaluate the diversity of plant community (Gu et al., 2015). Nonsignificant difference was found between IC and OC treatment for the same farm. This result was coincident with the results of Gu et al. (2015) and Yan and Lu (2015).

Vegetation cover is an important parameter to estimate soil degeneration rate and can reflect the horizontal distribution of plants (Wang, 1996). There were more than 100 species detected in our experimental area (Animal Husbandry Division Office of Maqu County, 1986). According to the functional groups, the dominant species on the alpine meadow of QTP were the families of *Gramineae* and *Cyperaceae*, forbs species, and noxious species, so they were the focus of this study. Short-term grazing exclusion had significant or nonsignificant effect on the coverage of these functional groups. This was consistent with a previous study that showed that the coverage between fenced and unfenced plots had nonsignificant difference in the first year but peaked in the fourth year for both treatments (Miao et al., 2012). However, another study also demonstrated that 1 yr enclosure greatly increased the coverage of degraded vegetation on the alpine meadow of QTP (Zhao et al., 2011). The discrepancy may due to the different grazing rates and degree of grassland degradation in this study.

On the alpine meadow of QTP, livestock production mainly depends on forage condition of pasture. Forage yield and quality has huge influences on livestock production (Zhao, 2010). Feed quality on alpine meadow was shown to be high in CP, ether extract, N free extract and calorific value but low in crude fiber (CF) (Zhao et al., 2000). There are three levels of feed balance and in order to reach the feed balance, seasonal change of nutrients must be understood (Yang et al., 2012). Wu et al. (2009a) reported that, in the area of the Yellow River, CP content on *Kobresia tibetica* meadow peaked in August and then declined, but CF increased from August to the following January. Similar results were obtained in this study as the CP content peaked in July and then decreased gradually, and ADF and NDF increased from July to October whether it was grazed or not.

Grasses are considered as the medium for the transfer of nutrients from the environment to animals. The aim of animal production is to provide humans with animal protein. In QTP, animals severely lack protein feed, which restricts the development of livestock productivity (Long et al., 1999). In addition, Tibetans traditionally burn yak dung as fuel, which leads to nutrient loss in grasslands and block the N cycle (Yu, 2010). Hou et al. (2002) pointed out that this activity breaks the coupling between vegetation and the soil system. Therefore, it may be the direct reason for lack of N in soil, leading in turn, to the lack of N in grasses. Fencing does not add extra N to the soil, so short-term grazing exclusion could not improve the forage quality. However, this 2 yr study demonstrated that short-term rest had different effects on CP content for the three pastures and it could increase forage CP in pastures under heavy animal load such as farmer 1.

On the alpine meadow of QTP, soil depth is usually 20-60 cm; below this is the soil parent material filled with gravel (Li et al., 1996). Fencing is an effective method with regard to the soil's storage ability to C and N in alpine meadow of the QTP (Wu et al., 2010). The present study showed that the soil moisture at 0 to 10 cm and 10 to 20 cm changed dramatically. This is because, in this area, soil moisture mainly depends on rainfall and rainfall has a much greater influence on the upper soil layer (Liu et al., 2008). Besides, rainfall is mainly distributed in June to September (data not shown). The soil moisture varied between the three pastures and pasture 1 had the lowest value due to the highest animal load (Table 1) and low biomass (Table 3). The increased evaporation and wind speed near the ground resulted in low soil moisture (Liu et al., 2005; Wang et al., 2006b). For the same pasture, short-term grazing exclusion did not have a consistent influence on soil moisture at 0 to 20 cm, and significant difference were detected in the upper layer of soil profile in 2011 and 2012. This is mainly because that the rainfall had huge influence on the soil moisture especially for the treatments with lower vegetation cover.

In this 2 yr study, nonsignificant differences were found between 2011 and 2012 for DW of edible and inedible forage, percentage of edible forage, vegetation coverage, forage CP, ADF, and NDF probably due to similar stocking rates on each pasture in these 2 yr.

CONCLUSIONS

Short-term grazing exclusion could effectively increase the dry weight and crude protein content of edible forage, and decrease the neutral detergent fiber content during the utilization of summer pasture in the alpine meadows of the Qinghai-Tibet plateau and the other pastures with similar plant vegetation if pastures have heavy stocking rate. It also can increase the soil moisture content to some extent. This short-term rest management strategy is recommended for farms with a heavy stocking rate.

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