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Biomass and species richness of legumes of semiarid grassland of Inner Mongolia, China

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Abstract
For ecological sustainability, legumes play a significant role in grassland ecosystem. From 2006 to 2008, samples were collected and data were generated on species richness and above ground dry matter of legumes at 20 field sites of Inner Mongolia, China and the relationship between legumes species richness with legume above ground dry matter was analyzed. The study was carried out in grassland characterized by a semiarid climate. At least two legume species occurred in 68.8% of the sites studied. It was dominated by perennial legumes genera such as *Astragalus*, *Medicago* and *Caragana*. Average annual above ground dry matter was 5.97 g m^{-2} which accounted for 5.02% of total community. Our study found that above ground dry matter and species richness of legumes was low due to low precipitation and high temperature during the growing season in the grassland of Inner Mongolia.

Keywords: Biomass, Inner Mongolia, Legumes, Semiarid grassland, Species richness

Introduction
Nitrogen (N) is fundamental nutrient which regulates plant growth in terrestrial ecosystems (Chapin *et al*., 1986). In natural grasslands, symbiotic N_2 fixation by legumes is especially significant since application of artificial fertilizer is unrealistic (Cusack *et al*., 2009). Nitrogen fixation by legumes varies in different ecosystems with changes in environmental factors and plant species composition (Vitousek *et al*., 2002). Small changes in the rate of nitrogen input may cause large impact in nitrogen limited communities over time (Kindscher and Tieszen, 1998). Pasture and forage legumes are major source of nitrogen in natural grassland ecosystems (Smil, 1999; Herridge and Boddey, 2008). At the community level, N_2 fixing legumes help to increase community primary production (Marquard *et al*., 2009; Schmidtke *et al*., 2010) by increasing soil nitrogen availability (Spehn *et al*., 2002; Roscher *et al*., 2011). Inadequate nitrogen usually limits plant growth in many terrestrial ecosystems. Besides enhancing the quality with respect to protein content, the vegetative growth of plant is improved by addition of nitrogen (Katoch, 2010; Meena and Mann, 2010). Therefore, the role of symbiotic N_2 fixation in grassland ecosystem is vital. Legumes are also rich in protein and minerals which help to speed up the rate of digestion in animals (Van Soest, 1994).

Across China, about 1670 legume species from 180 genera were recorded (Jin *et al*., 2013). But about 500 legume species from 118 genera were found to modulate. These legumes are multi beneficial for ecosystem and human beings, but there is paucity of information on legumes and more studies are needed to identify the status and their roles in natural grasslands (Sprent and Gehlot, 2010). Previous studies on legumes focused mainly on cultivated legume species in managed grasslands. Grazing by livestock is the main anthropogenic disturbance in natural grasslands (Liu *et al.,* 2012) and it plays an important role in determining species composition and plant species diversity (Milchunas *et al.,* 1989). Uncontrolled and over-grazing makes the soils susceptible for degradation and adversely affects the sustainability of grasslands (Ghosh and Mahanta, 2014; Jaweed *et al*., 2015). Hence, grazing should be controlled to improve legume composition in grassland ecosystem. Again the climate of Inner Mongolia region varies from arid to semiarid (Turner *et al*., 2011) where 60% of the total area is covered by semiarid region (Guan *et al*., 2012). Earlier considerable studies were conducted on biomass productivity, water use and crop soil nitrogen dynamics in grassland of Inner Mongolia, but studies on association of legumes with precipitation is lacking. Therefore, our study was aimed to investigate the influence of precipitation and species richness on legumes biomass in semiarid grassland of Inner Mongolia.

Materials and Methods
***Study area*:** The field investigations were conducted in

the semiarid grasslands of Inner Mongolia in northern China at 20 sites in 2006, 2007 and 2008. Inner Mongolia is dominated by arid and semiarid temperate continental to continental monsoon climate. In the study sites, latitude ranged from 40⁰ 46′ N to 44⁰ 39′N and longitude from 111⁰ 11′E to 118⁰ 48′ E (Fig. 1). Mean annual temperature varied from 2.76⁰C to 6.76 ⁰C and mean annual precipitation ranged from 220.4 mm to 395.15 mm.

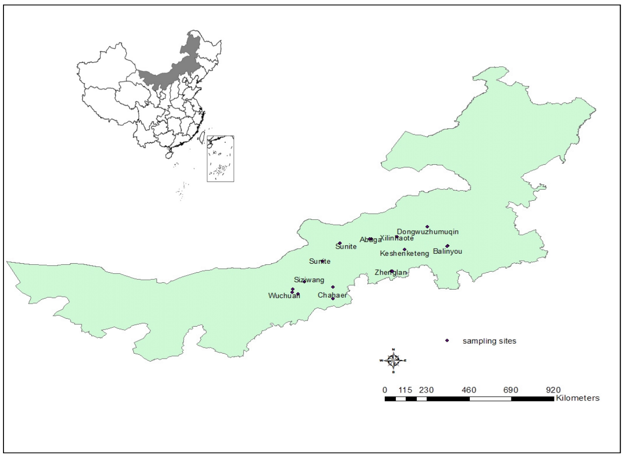

Fig 1. Study area and sampling sites in grasslands of Inner Mongolia.

***Data collection*:** At each site, 100m transect line was randomly located, within which three 1 m^2 plots along a line were surveyed. In each plot, plants were separated by species and above ground biomass was harvested at ground level. The above ground plant materials were oven dried at 80°C for 24 hours to obtain dry weight (g m^{-2}). The percentages of legume species richness and above ground dry matter relative to the total were also calculated. The mean annual temperature (MAT) and mean annual precipitation (MAP) during investigation years were obtained from meteorological stations located in or around sample sites from the China Meteorological Administration.

***Data analysis*:** First, the dominant legume genera in Inner Mongolia grasslands were determined by their percentage in frequency of occurrence across all sites. Legumes known to contain a variety of alkaloids toxic to livestock were also identified (Xi and Ma, 2003). We applied linear regression analysis to identify the relationship between legumes species richness and legume above ground dry matter and also to find relationship between legumes above ground dry matter with precipitation. Statistical analysis was performed using software package of SPSS 16.0 (SPSS Inc., Chicago, and IL., USA).

Results and Discussion

***Composition of legumes and biomass*:** Of the studied sites, 68.8% had at least two legume species. On the basis of frequency of occurrence *Astragalus*, *Medicago* and *Caragana* were the three dominant legume genera in Inner Mongolia grasslands and were present in 32.3%, 21.5%, and 15.3% of the sites, respectively (Table 1).

Table 1. Frequency and mean above ground dry matter of legume genera in 20 sites on Inner Mongolia grasslands

Legume genera	Frequency (%)	Above ground dry matter (g m^{-1})
Astragalus	32.30	28.11
Oxytropis	10.76	2.21
Medicago	21.53	11.92
Caragana	15.38	27.62
Lespendeza	13.84	25.83
Gueldenstaedtia	6.15	0.26
Thermopsis	3.07	0.24

Overall, 7 legume genera, (*Astragalus*, *Oxytropis*, *Medicago*, *Caragana*, *Lespedeza*, *Gueldenstaedtia* and *Thermopsis*) were recorded, all of which belong to the subfamily *Papilionoideae* (Table 2). Within 1 m^2 of grassland, only 2 legume species with an above ground dry matter of 5.97 g was present, accounting for 13.13% of species richness and 5.02% of the above ground dry matter of the community. In our study above ground dry matter of legumes ranged from 0.82 to 38.79 g m^{-2}. Similarly, Jin *et al.* (2013) also recorded above ground dry matter of legumes of Inner Mongolia and the values were ranged from 0.1 to 40 g m^{-2}. Overall, 9 legume species were recorded, and among them 7 species were forage legumes and 2 species were toxic legumes (Table 3). Thus diversity in legume genera with some forage species was found in the grassland of Inner Mongolia.

Table 2. Legume species richness, above ground dry matter and their percentages of the corresponding parameters in communities

Species richness		Above ground dry matter (g m^{-2})	
LSR	2	LDM	5.97
CSR	12.94	CDM	118.71
PLSR	13.13	PLDM	5.02

Note: *LSR indicates legume species richness; CSR indicates species richness of a community; PLSR indicates percentage of legume species richness in a community; LDM indicates above ground dry matter of legumes; CDM indicates above ground dry matter of a community; PLSR indicates percentage of above ground dry matter of legumes in a community*

Table 3. Forage and toxic legumes observed in 20 sites from grassland of Inner Mongolia

Forage legumes	Toxic legumes
Astragalus adsurgens	*Oxytropis aciphylla*
A. melilotoides	*Thermopsis lanceolata* [6,7]
Medicago ruthenica	
Caragana microphylla	
Lespendeza davurica	
Gueldenstaedtia diversifolia[7]	
Vicia sepium[6,7]	

Note: [6,7]indicates legume species which were not observed in the year 2006 and 2007 and [7]indicates legume species which were not observed in the year 2007.

***Associations between legume above ground dry matter and species richness*:** Positive correlations between legume above ground dry matter and species richness in the year 2006 (R^2 = 0.330, $P<0.05$, Fig. 2a), 2007(R^2 = 0.254, $P<0.05$, Fig. 2b) and 2008 (R^2 = 0.293, $P<0.05$, Fig. 2c) were found in Inner Mongolia. This finding is consistent with the commonly held view that there is positive linear relationship between productivity and species richness in natural grassland ecosystem (Bai *et al*., 2000, 2007; Ma and Fang 2005). However, both legume species richness and above ground dry matter showed no correlation with non-legume species richness and above ground dry matter in same region. Therefore, species richness plays an important role in production of legume above ground dry matter in Inner Mongolia grassland of China.

***Weather conditions*:** Weather parameters did not change widely during the three growing seasons of the experiment. Mean temperature for the five months (May–September) of the three growing seasons in the year 2006, 2007 and 2008 were 18.11 ^{0}C, 19.24 ^{0}C and 17.60 ^{0}C, respectively. Similarly the growing season precipitation of the year 2006, 2007 and 2008 were 345 mm, 277 mm and 466 mm, respectively. These data showed that the third growing season precipitation was highest in 2008 and lowest in 2007 whereas, growing season temperature was highest in 2007 and lowest in 2008. There was no significant relationship between the growing season precipitation and temperature with legumes above ground dry matter and species richness. Previous studies (Wardle *et al.,* 1999; Striker *et al.,* 2011) showed that in natural grassland legumes biomass was higher than that in temperate grassland of Inner Mongolia. This is due to low precipitation in the growing season in the grassland of Inner Mongolia. Extreme climatic variables (e.g. drought) may even restrict the number of grassland species (Tilman and El Haddi, 1992). On the other hand, Koukoura and Papanastasis (1997) found that legume abundance was correlated with air temperature and precipitation. Similar results were also reported by Fernandez Ales *et al*. (1993) in Spain, who found that legume abundance was particularly influenced by spring precipitation. In our study great reduction of legume above ground dry matter in the dry year 2007 was attributed to the adverse lowest precipitation conditions of the months May, June and September as shown below in figure 3 which is the peak season of growing legumes.

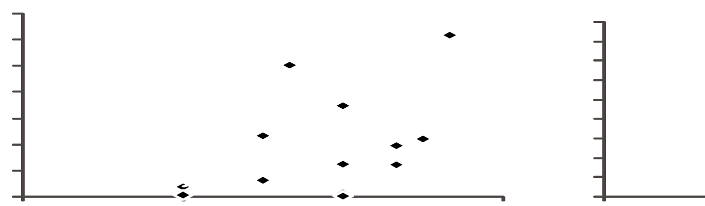

Fig 2. Relationship of legumes above ground dry matter (g m^{-2}) with species richness in year (a) 2006 site (b) 2007 site (c) 2008 site and (d) mean of the year 2006, 2007 and 2008

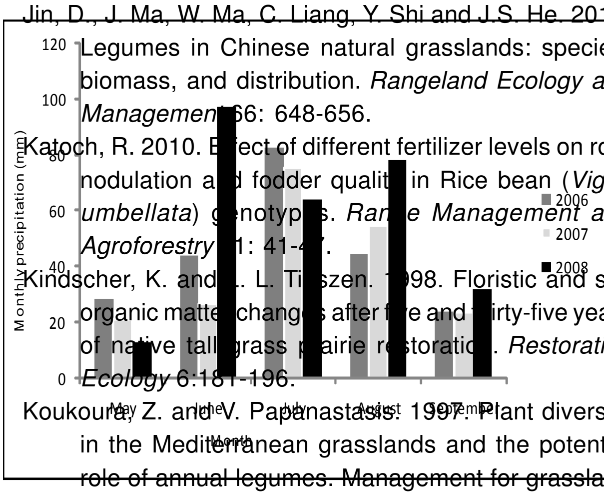

Fig 3. Growing season monthly precipitation

Conclusion

Legumes especially play an important role for maintaining grassland biomass production. One of the main factors for lower legume biomass in Inner Mongolia was low precipitation, therefore, to increase legume biomass in these grasslands; plantation of legume species and provision of irrigations during the growing season are strongly recommended.

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References

Bai, Y.F., L.H. Li, Q. B. Wang, L.X. Zhang, Y. Zhang and Z. Z Chen. 2000. Changes in plant species diversity and productivity along gradients of precipitation and elevation in the Xilin River Basin, Inner Mongolia. *Acta Phytoecologica Sinica* 24: 667-673.

Bai Y.F., J.G. Wu, Q.M. Pan, J.H. Huang, Q. B. Wang, F. Li, A. Buyantuyev and X. G. Han. 2007. Positive linear relationship between productivity and diversity: evidence from the Eurasian Steppe. *Journal of Applied Ecology* 44: 1023-1034.

Chapin III, F. S., P.M. Vitousek and K. V. Cleve. 1986. The nature of nutrient limitation in plant communities. *American naturalist* 1: 48-58.

Cusack, D. F., W. Silver and W.H. McDowell. 2009. Biological nitrogen fixation in two tropical forests: ecosystem-level patterns and effects of nitrogen fertilization. *Ecosystems* 12: 1299-1315.

Fernández Alés, R., J.M. Laffarga and F. Ortega. 1993. Strategies in Mediterranean grassland annuals in relation to stress and disturbance. *Journal of Vegetation Science* 4: 313-322.

Ghosh, P.K. and S.K. Mahanta.2014. Carbon sequestration in grassland systems. *Range Management and Agroforestry* 35: 173-181.

Guan, X. K., X.H. Zhang, N. C. Turner, B.C. Xu and F.M. Li. 2012. Two perennial legumes (*Astragalus* adsurgens Pall. and *Lespedeza davurica* S.) adapted to semiarid environments are not as productive as lucerne (*Medicago sativa* L.), but use less water. *Grass and Forage Science* 68: 469-478.

Herridge, D. F. and R. M. Boddey. 2008. Global inputs of biological nitrogen fixation in agricultural systems. *Plant and Soil* 311: 1-18.

Jaweed, T.H., P.G. Saptarshi and S.W. Gaikwad. 2015. Impact of transhumant grazing on physical and chemical properties of soils in temperate pasturelands of Kashmir Himalaya. *Range Management and Agroforestry* 36: 128-135.

Jin, D., J. Ma, W. Ma, C. Liang, Y. Shi and J.S. He. 2013. Legumes in Chinese natural grasslands: species, biomass, and distribution. *Rangeland Ecology and Management* 66: 648-656.

Katoch, R. 2010. Effect of different fertilizer levels on root nodulation and fodder quality in Rice bean (*Vigna umbellata*) genotypes. *Range Management and Agroforestry* 31: 41-47.

Kindscher, K. and L. L. Tieszen. 1998. Floristic and soil organic matter changes after five and thirty-five years of native tallgrass prairie restoration. *Restoration Ecology* 6:181-196.

Koukoura, Z. and V. Papanastasis. 1997. Plant diversity in the Mediterranean grasslands and the potential role of annual legumes. Management for grassland biodiversity. In: Proc. The international occasional symposium EGF (Vol. 2: 221-226).

Liu, N., Y. Zhang, S. Chang, H. Kan and L. Lin. 2012. Impact of grazing on soil carbon and microbial biomass in typical steppe and desert steppe of Inner Mongolia. *Plos one* 7: p.e36434.

Marquard, E., A. Weigelt, V. M. Temperton, C. Roscher, J. Schumacher, N. Buchmann, M. Fischer, W.W. Weisser and B. Schmid. 2009. Plant species richness and functional composition drive over yielding in a six-year grassland experiment. *Ecology* 90: 3290-3302.

Ma, W. H. and J.Y. Fang. 2005. The relationship between species richness and productivity in four typical grasslands of northern China. *Chinese Biodiversity* 14: 21-28.

Meena, L. R. and J. S. Mann. 2010. Response of barley to nitrogen management at varying growth stages under semiarid conditions of Rajasthan. *Range Management and Agroforestry* 31: 20-23.

Milchunas D.G, W. K. Lauenroth and P. L. Chapman. 1989. Effects of grazing, topography, and precipitation on the structure of a semiarid grassland. *Vegetation* 80: 11–23.

Roscher, C., S. Thein, A.Weigelt, V. M. Temperton, N. Buchmann and E.D. Schulze. 2011. N_2 fixation and performance of 12 legume species in a 6-year grassland biodiversity experiment. *Plant and Soil* 341: 333-348.

Schmidtke, A., T. Rottstock, U. Gaedke and M. Fischer. 2010. Plant community diversity and composition affect individual plant performance. *Oecologia* 164: 665-677.

Smil, V. 1999. Nitrogen in crop production: An account of global flows. *Global Biogeochemical Cycles* 13: 647-662.

Spehn, E. M., M. S. Lorenzen, B. Schmid, A. Hector, M. C. Caldeira, P.G. Dimitrakopoulos, J. A. Finn, A. Jumpponen, G. O'donnovan, J.S. Pereira and E.D. Schulze. 2002. The role of legumes as a component of biodiversity in a cross-European study of grassland biomass nitrogen. *Oikos* 98: 205-218.

Sprent, J. I., and H.S. Gehlot. 2010. Nodulated legumes in arid and semiarid environments: are they important? *Plant Ecology and Diversity* 3:211-219.

Striker, G. G., F. P. O. Mollard, A. A. Grimoldi, R. J. C. León and P. Insausti. 2011. Trampling enhances the dominance of graminoid over forbs in flooded grassland mesocosms. *Applied Vegetation Science* 14: 95-106.

Tilman, D. and A.E. Haddi. 1992. Drought and biodiversity in grasslands. *Oecologia* 89: 257-264.

Turner, N. C., N. Molyneux, S. Yang, Y.C. Xiong and K. H. Siddique. 2011. Climate change in south-west Australia and north-west China: challenges and opportunities for crop production. *Crop and Pasture Science* 62:445-456.

Van Soest, P. J. 1994. *Nutritional Ecology of the Ruminant*. Cornell University Press. Ithaca, New York.

Vitousek, P. M., K. Cassman, C. Cleveland, T. Crews, C. B. Field, N.B. Grimm, R.W. Howarth, R. Marino, L. Martinelli, E.B. Rastetter and J.I. Sprent. 2002. Towards an ecological understanding of biological nitrogen fixation. *Biogeochemistry* 57: 1-45.

Wardle, D. A., K. I. Bonner, G. M. Barker, G.W. Yeates, K.S. Nicholson, R.D. Bardgett, R. N. Watson and A. Ghani. 1999. Plant removals in perennial grassland: vegetation dynamics, decomposers, soil biodiversity, and ecosystem properties. *Ecological Monographs* 69: 535-568.

Xi, L.I. and L.P. Ma. 2003. Current research progress on grassland poisonous weeds *Oxytropis. Grassland and Turf* (*Chinese*) 3: 19–22.