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# Responses of different Collembola and mite taxa to experimental rain pulses in an arid ecosystem

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ABSTRACT

Precipitation in arid ecosystems occurs as rain pulses, namely infrequent, discrete and unpredictable events of variable intensity. Rain pulses have impacts on activity patterns of macroarthropods, but their impacts on activity patterns of microarthropods are not fully known. Here, we designed a rainfall manipulative experiment in an arid ecosystem (MAP = 117 mm) in Gansu province, northwestern China to examine short-term activity responses of two dominant microarthropod groups, Collembola and mites, to experimental rain pulses. We added water in one large 15-mm event (large pulse) and in three separate small 5-mm events (small pulses), six days apart. We had control plots without water addition. After watering treatment, we measured microarthropods and soil moisture content (SMC) and temperature (ST) over a period of 15 days. The study period was split into an initial response stage (first 5 days; IRS), a prolonged response stage (next 5 days; PRS) and a final response stage (last 5 days; FRS). Both pulse treatments did not affect the number of microarthropod taxa, but significantly increased the number of microarthropods relative to the control, with a greater increase in large than small pulses in PRS and FRS. Within the Collembola assemblage, both pulse treatments significantly increased the number of Entomobryidae, but did not affect the numbers of Hypogastruridae, Isotomidae and Sminthuridae. Within the assemblage of mites, both pulse treatments significantly decreased the number of Oribatida, but did not affect the numbers of Astigmata, Mesostigmata and Prostigmata. Across three response stages, the number of oribatid mites was negatively correlated with SMC and positively correlated with ST, while the number of entomobryid springtails was positively correlated with SMC and negatively correlated with ST. Our results provide experimental evidence that the microarthropod community was strongly affected by short-term experimental rain pulses, but this effect varied acros taxa, experimental stages and pulse sizes.



## 1. Introduction

Water availability is one of the main environmental variables controlling patterns of the growth and reproduction of plants and animals in arid and semiarid ecosystems, influencing population sizes and species composition in communities (Noy-Meir, 1973; Cloudsley-Thompson, 1975; Mackay et al., 1986; Dean and Milton, 1995; Ogle and Reynolds, 2004; McCluney et al., 2012). Precipitation in arid ecosystems usually occurs as rain pulses, namely infrequent, discrete and unpredictable events of variable intensity (Noy-Meir, 1973; Austin et al., 2004). Many studies have shown that rain pulses can have significant effects on patterns of soil fauna community abundance and diversity in arid and semiarid ecosystems (Huxman et al., 2004; Jenerette et al., 2008; Blankinship et al., 2011; Nielsen and Ball, 2015).

However, the relative influence of rain pulses on soil fauna abundance and diversity patterns may vary depending on their intensity (Taylor et al., 2004; McCluney et al., 2012). This is because changes in rain pulse intensity would affect soil moisture conditions differently (Loik et al., 2004; Nielsen et al., 2008), which in turn result in large differences in the degree of response of soil fauna. Moreover, the relative influence of rain pulses may also vary between different taxa of soil fauna (Wu et al., 2014; Kwok et al., 2016). Different soil fauna taxa will show substantial variation in their sensitivity to pulse sizes, largely because of differences in their biological and ecological characteristics, including trophic position (Taylor et al., 2004; Lindo et al., 2012), feeding strategy and life history (Siepel, 1994; Gongalsky et al., 2008), dispersal ability (Lehmitz et al., 2012) and resource requirements (Block et al., 2009). Therefore, understanding how different soil fauna taxa respond to changes in rain pulse intensity is crucial for predicting their sensitivity to global environmental change.

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Previous studies of arid and semiarid ecosystems have examined how rain pulse sizes influence the dynamics of biogeochemical cycles (Liu et al., 2002; Austin et al., 2004; Huxman et al., 2004; Sponseller, 2007; Chen et al., 2009; Yahdjian and Sala, 2010; Nielsen and Ball, 2015). Research exploring the influence of rainfall change on biological communities has primarily focused on long-term outcomes (e.g., Soil microbes, Huang et al., 2015; soil protozoa, Darby et al., 2011; soil nematodes, Vandegehuchte et al., 2015; soil microarthropods, O'Lear and Blair, 1999; Chikoski et al., 2006; Holmstrup et al., 2013; Wu et al., 2014; beetles and spiders, Whitford, 2002; birds, Dean and Milton, 2001). However, relatively few studies have examined short-term activity responses of microarthropods to changes in rain pulse intensity and duration in arid ecosystems (but see Tsiafouli et al., 2005). Soil microarthropods play a key role in regulating ecosystem processes and functions by influencing litter decomposition, nutrient mineralization and microbial activity in the arid and semiarid ecosystems (Whitford, 1996; Whitford, 2002). Collembola and mites are the dominant groups of microarthropods in the temperate desert ecosystems of northwestern China (Li et al., 2013). To date, knowledge on the response of these important microarthropod groups to changes in the intensity of rain pulses is limited.

In this study, we conducted a rainfall manipulation experiment in an arid ecosystem in Gansu province, northwestern China, to examine short-term activity responses of different taxa of Collembola and mites to experimental rain pulses. In this experiment, we added water in one large 15-mm event (large pulse) and in three separate small 5-mm events (small pulses), six days apart, while maintaining the same amount of water addition in both pulse treatments. We had control plots, without water addition. The main objectives of this study were to quantify: (1) changes in activity patterns of overall microarthropods and different taxa of Collembola and mites under two experimental pulse sizes and (2) possible relationships between the community composition and diversity of overall microarthropods and their taxa and soil moisture and soil temperature. We expected that microarthropod responses to experimental pulse sizes would vary among taxa and among experimental stages.

## 2. Materials and methods

### 2.1. Site description

The study was conducted in an arid region of the western Gansu Province, northwestern China (39°21′ N, 100°07′ E; 1384 m a.s.l.). This region has a temperate-arid climate, with a mean annual temperature of 7.6 °C and a mean annual precipitation of 117 mm. About 13%, 28%, 19% and 17% of the annual precipitation falls in June, July, August and September, respectively (from 1995 to 2014 data). Mean annual pan-evaporation is approximately 2390 mm, 20 times larger than annual precipitation. The natural vegetation is sandy grassland, dominated by shrub species *Haloxylon ammodendron* (C. A. Mey.) Bunge ex Fenzl, *Calligonum mongolicum* Turcz., *Nitraria sphaerocarpa* Maxim. and *Nitraria sibirica* Pall., along with herbaceous species such as *Bassia dasyphylla* (Fisch. & C. A. Mey.) Kuntze, *Halogeton glomeratus* (M. Bieb.) Ledeb., *Agriophyllum squarrosum* (L.) Moq. and *Echinops gmelinii* Turcz. (Zhang and Zhao, 2015).

### 2.2. Experimental design and manipulations

In the study region, precipitation occurs in small (≤5 mm; 82.2% of all events), moderate to large (6–15 mm; 14.1% of all events) and heavy (>15 mm; 3.7% of all events) events (1995–2014 data from Linze Inland River Basin Research Station, Chinese Academy of Sciences).

We conducted a rainfall manipulative experiment in a long-lived shrub (*H. ammodendron*) plantation with an area of approximately 34 ha. The plantation was established in 1999 on natural sandy grassland at the fringe of human-inhabited oases as shelterbelts (Chang et al., 2014). Existing shrub density is 8.0 ± 1.0 (mean ± s.e.) plants per 100 $m^2$ and understory herbaceous cover is 4.2 ± 0.7%. The chemical mineral composition of parent material and the physicochemical properties in the plantation soil were shown in Table 1.

In late August 2014, 18 similarly sized, adult *H. ammodendron* shrubs (height: 3.2 ± 0.2 m and mean canopy diameter: 3.0 ± 0.1 m) were used. Each selected plant was at least 7 m away from its nearest neighbor. For experimental irrigation, we established 4 m × 4 m plots centered on each of the 18 shrubs (Fig. 1a). The 12-cm high brick wall was installed around each plot to prevent surface runoff from the plots during watering. The wall had channels to allow free movement of arthropods.

Six plots were randomly assigned to large pulse treatment, in which 15 mm of previously collected rainwater was evenly sprayed with a homemade water sprinkler equipment, achieved by adding 240 l/plot at a rate of about 8 l/min ($P_{15}$). Another six plots were randomly assigned to small pulse treatment, in which the same amount of previously collected rainwater was evenly sprayed with a homemade water sprinkler equipment in three different times, achieved by adding 80 l/plot each at a rate of about 8 l/min, 6 days apart ($P_{3 \times 5}$). The remaining six were control plots, without water addition ($P_0$). In this experiment, two sets of sprinkler equipment were applied. The sprinkler equipment comprises 16 spray nozzles arranged in four rows (four nozzles per row) with a distance of 1 m between any 2 nozzles to cover the 16 $m^2$ plot (Fig. 1b, c).

The amount of natural rainfall during the study period was recorded with an automatic meteorological station at a distance of about 150 m from the experimental plots.

### 2.3. Microarthropod sampling and measurements of soil moisture and temperature

Our previous investigation of Collembola and mites in such sandy grasslands indicates that pitfall trapping was the ideal method for sampling of these ground-dwelling microarthropods because we failed to extract collembolans and mites from soil samples using modified Berlese-Tullgren method (Kimberling et al., 2001; Sabu and Shiju, 2010). Pitfall trapping was therefore applied in this experiment.

At the second day of the watering application, we measured microarthropod activity density every day (24 h) using pitfall traps for a period of 18 days from 4 to 21 September 2014, including 3 days of the watering application (September 4, 10 and 16, respectively) that

**Table 1**
The chemical mineral composition of parent material and the physicochemical properties in soils (0–20 cm) of natural grassland (NG) and shrub (*Haloxylon ammodendron*) plantation (HAP).

| | NG | HAP |
|---|---|---|
| *Parent material properties* | | |
| $Al_2O_3$ (g $kg^{-1}$) | 98.8 ± 1.3 | 103.3 ± 1.4 |
| $TFe_2O_3$ (g $kg^{-1}$) | 27.1 ± 1.0 | 26.9 ± 0.5 |
| CaO (g $kg^{-1}$) | 34.1 ± 1.2 | 34.6 ± 0.5 |
| MgO (g $kg^{-1}$) | 15.0 ± 0.5 | 14.9 ± 0.3 |
| $Na_2O$ (g $kg^{-1}$) | 21.8 ± 0.2 | 21.1 ± 0.2 |
| $K_2O$ (g $kg^{-1}$) | 23.7 ± 0.3 | 24.8 ± 0.3 |
| *Physical properties* | | |
| Coarse sand (2–0.25 mm, %) | 25.1 ± 1.5 | 21.5 ± 1.3 |
| Fine sand (0.25–0.05 mm, %) | 75.6 ± 1.6 | 77.0 ± 1.3 |
| Silt plus clay (<0.05 mm, %) | 0.5 ± 0.1 | 1.5 ± 0.1 |
| Bulk density (g $cm^{-3}$) | 1.58 ± 0.02 | 1.52 ± 0.02 |
| Field capacity (%) | 7.4 ± 0.4 | 8.2 ± 0.5 |
| *Chemical properties* | | |
| pH | 9.2 ± 0.1 | 8.7 ± 0.1 |
| Organic carbon (g $kg^{-1}$) | 0.58 ± 0.1 | 0.64 ± 0.1 |
| Total nitrogen (g $kg^{-1}$) | 0.09 ± 0.01 | 0.07 ± 0.01 |
| Total phosphorus (g $kg^{-1}$) | 0.25 ± 0.02 | 0.27 ± 0.01 |