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The effects of precipitation timing on sagebrush steppe vegetation

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Abstract

Changes in precipitation patterns and inputs have the potential to cause major changes in productivity, composition, and diversity of terrestrial plant communities. Vegetation response to altered timing of precipitation was assessed during a 7-year experiment in an *Artemisia tridentata* spp. *wyomingensis* community in the northern Great Basin, USA. Four permanent rainout shelters excluded natural rainfall, with seasonal distribution of precipitation controlled with the use of an overhead sprinkler system. Precipitation treatments under each shelter were WINTER, SPRING, and CURRENT. The WINTER treatment received 80% of its water between October and March; in the SPRING treatment 80% of total water was applied between April and July; and the CURRENT treatment received precipitation matching the site's long-term (50 years) distribution pattern. A CONTROL treatment, placed outside each shelter replicate, received natural precipitation inputs. CURRENT, WINTER, and CONTROL treatments had similar in soil water-content patterns and thus, there were few consistent differences in vegetation response. The SPRING treatment resulted in more bare-ground and lower plant productivity compared to other shelter treatments. This result contrasted with our initial hypothesis that shallower-rooted grasses would gain a competitive advantage over shrubs if precipitation was shifted from winter to spring. Our results also demonstrated the resilience of these communities to climate perturbation as many of the vegetation shifts did not begin until the fourth year after treatments were applied.

Keywords: Climate change; Cheatgrass; Great basin; Precipitation patterns; Plant succession

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1. Introduction

Precipitation exerts primary control of plant productivity and composition in semi-arid and arid land plant communities (Pechanec et al., 1937; Noy-Meier, 1973; Passey et al., 1982; Graetz et al., 1988). The frequency and seasonal distribution of precipitation play a major role in the availability of water within soil profiles, thus, strongly influencing arid land plant composition and dynamics (Graetz et al., 1988; Comstock and Ehleringer, 1992; Ojima et al., 1993; Ehleringer et al., 1999). Winter precipitation is more likely to percolate deeper into the soil profile, whereas, summer precipitation may evaporate before infiltrating (Schwinning et al., 2003). In the northern Great Basin of the United States, the majority of annual precipitation is received during the winter and early spring. This climatic regime favors growth and development of deep-rooted shrubs and cool season plants using the C_3 photosynthetic pathway (Comstock and Ehleringer, 1992). The prevalence of summer precipitation on the Colorado Plateau and Great Plains results in a higher proportion of shallower-rooted summer active species using the C_4 photosynthetic pathway (Comstock and Ehleringer, 1992; Cook and Irwin, 1992).

Climate change brought on by anthropogenic activities forecasts not only global warming but alteration of precipitation regimes by affecting timing, frequency, and intensity of precipitation events (Easterling et al., 2000; NAST, 2000; IPCC, 2001). Alteration of precipitation patterns has the potential to cause major changes in vegetation, soils, biodiversity, and ecological processes in terrestrial ecosystems (Neilson et al., 1989; Brown et al., 1997; Ehleringer et al., 2001). Experimental evidence indicates that reducing storm frequency and increasing rainfall quantity per storm increases temporal variability of soil moisture and decreases above-ground production in tall grass prairie of the central United States (Fay et al., 2002; Knapp et al., 2002). Shifting from a winter to spring precipitation pattern reduced productivity in the sagebrush steppe of the northern Great Basin (Svejcar et al., 2003, pp. 90–106). Atmospheric increases in CO_2 and climate change also have the potential to increase the competitiveness of invasive weeds in arid lands as documented by increased *Bromus tectorum* productivity in response to elevated CO_2 in southern Nevada (Smith et al., 2000).

We investigated the effects of altered timing of precipitation to vegetation dynamics in an *Artemisia tridentata* spp. *wyomingensis* community in the northern Great Basin over 7 years. We hypothesized that herbaceous plants, particularly perennial grasses, would better adapt to a shift toward a spring precipitation distribution and productivity and composition would either remain stable or increase. Perennial grasses in this system have more shallow-fibrous roots compared to *A. tridentata* (Branson et al., 1976; Reynolds and Fraley, 1989; Dobrowolski et al., 1990). Evidence from ecological studies conducted in our area indicated that cool season species would respond to late spring and summer moisture with increased growth (Bates et al., 2000). We also hypothesized that a shift to a greater percentage of winter precipitation would increase cover and recruitment of *A. tridentata* compared to herbaceous perennials. Increased winter precipitation was expected to enhance water recharge in the lower part of the soil profile and thus favor