Height Growth of Planted Shrubs and Trees in a Semiarid Rangeland in Western Montana

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Abstract

We evaluated height development of restoration species in two studies in the semiarid foothills of the Sapphire Range in western Montana. In one study, ponderosa pine (*Pinus ponderosa* Lawson & C. Lawson) and Rocky Mountain juniper (*Juniperus scopulorum* Sarg.) that were planted on a partially degraded site were given supplemental irrigation for 2 years, after which irrigation was discontinued for a subset of plants. Subsequent height growth did not differ, indicating that irrigation after plants have established and reached a certain level of maturity may not provide an advantage. In the other study, Rocky Mountain juniper, antelope bitterbrush (*Purshia tridentata* [Pursh] DC.), and mountain mahogany (*Cercocarpus ledifolius* Nutt.) were planted on dry, south-facing slopes and measured for annual growth. Plants grew 5 to 30 percent during the first two seasons and 49 to 73 percent in the third season. These results help provide realistic expectations for restoration plantings in semiarid sites.

Introduction

Native plant communities in rangelands across the Western United States have been altered by overgrazing (Fleischer 1994), nonspecific herbicide use (Crone et al. 2009), and conversion to agriculture (Wright and Wimberly 2013). These disturbances can cause soil compaction (Hamza and Anderson 2005), erosion (Montgomery 2007), and invasion by exotic plants (Hobbs and Huenneke 1992). The resulting habitat often supports lower biodiversity and less ecological value (Fleischer 1994) than undisturbed habitats, thereby necessitating revegetation to restore the natural ecology of the landscape (Brennan and Kuvlesky 2005).

One component of restoring rangelands can be increasing shrub and tree cover (Brennan and Kuvlesky 2005). In many areas, topographical features, such as the north sides of hills and draws, create unique microclimates that can favor certain plant species and other biota (Bennie et al. 2008) that may otherwise not be present in a rangeland (Suggitt et al. 2011). Some wildlife species, including birds that rely on these habitats, are in decline (Brennan and Kuvlesky 2005). Increasing shrub and tree cover may create habitat while also establishing wildlife corridors that connect habitat patches and facilitate wildlife travel (Beier and Noss 1998).

Many rangelands in the Intermountain West have arid or semiarid climates that make restoring shrubs and trees difficult. Lack of precipitation often precludes natural establishment in these areas, so introduced plants must often be irrigated during the initial establishment (Bainbridge 2002). Watering plants by hand or installing drip irrigation in areas that might not be easily accessed requires additional labor and cost (Bainbridge 2002). Planted shrubs and trees can also be browsed or damaged by ungulates, requiring the installation of fences, exclosures, or other deterrents (Johnson and Okula 2006, Kimball et al. 2005), further increasing labor and cost. Considering these challenges, it is critical to have realistic estimates about plant growth and survival so that the magnitude of success can be predicted.

The objective of our study was to determine height growth of shrub and tree species on rangeland sites in western Montana. Land managers and restoration practitioners can use these data to estimate growth rates for species planted at similar sites.

Methods

Study Area

We conducted two studies at MPG Ranch (Florence, MT) in the foothills of the Sapphire Range in western Montana (46° 40’ 48” N, 114° 1’ 40” W, 1000 m [~3,300 ft]; mpgranch.com). The area received an average of 20 cm (8 in) of precipitation annually from 2010 to 2015. The topography consists of rangelands and draws. Based on oral history records, much of the area was sprayed with broadleaf herbicides and grazed from 1972 to 2007. As a result, the land suffers from erosion, soil compaction, a high cover of exotic plants, and a low cover of native shrubs and trees. We established two study sites in the area based on habitat type: partially degraded and south-facing slopes.

Partially Degraded Site

The partially degraded site was along a roadside in an area (about 300 m [~1,000 ft] long and 30 m [~100 ft] wide) that had a history of heavy cattle grazing and human disturbance. The site had compacted soils and was invaded by weeds, including tumble mustards (*Sisymbrium* spp.), kochia (*Bassia scoparia* [L.] A.J. Scott), leafy spurge (*Euphorbia esula* L.), and cheatgrass (*Bromus tectorum* L.). Between mid-April and mid-May in 2010 and 2011, we planted Rocky Mountain juniper (*Juniperus scopulorum* Sarg.; n = 265) and ponderosa pine (*Pinus ponderosa* Lawson & C. Lawson; n = 78) seedlings on the site (figure 1).

The Franklin H. Pitkin Forest Nursery at the University of Idaho (Moscow, ID) grew the seedlings as containerized stock (328 cm^3 [20 in^{3-}], with the exception of approximately 10 percent of the ponderosa pine seedlings grown in larger containers) for approximately 15 months. Seeds for ponderosa pine were sourced from the University of Idaho Experimental Forest (Moscow, ID) at an elevation of 945 m (3,100 ft). Rocky Mountain juniper seeds either were sourced from a location in Utah or were Bridger Select from Montana (Scianna et al. 2000). Watershed Consulting (Missoula, MT) planted all the seedlings in microsites that appeared suitable for growth and were spaced a minimum of 1 m (~3 ft) apart. We placed wood chips around the base of each plant and

Figure 1. Rocky Mountain juniper and ponderosa pine were planted near the edge of a road on the partially degraded site. (Photo by Michael McTee, 2015)

installed plastic exclosures (48 by 117 cm [19 by 46 in]) supported with wooden stakes around each plant to exclude browse by ungulates (figure 1). We placed identification tags on every exclosure.

During 2010 and 2011, all plants were hand watered approximately every 2 weeks with 3.8 to 11.4 L (1 to 3 gal) of water. In 2012, we installed drip irrigation to all plants, which delivered a rate of 3.8 L (1 gal) of water per hour for 4 to 8 hours every 2 weeks. In 2013, drip irrigation was removed from a randomly selected subset of 7 to 10 plants of each species (table 1) to test whether irrigation influenced height growth after the plants were established. Drip irrigation continued on all other plants through 2015. Plant heights were measured annually at the end of the growing season, in September, from 2012 to 2015 by removing woodchips at the base of the plant and measuring the distance from the soil to the tallest growth leader.

For each species, we tested for differences between the heights of those plants that did or did not receive irrigation. We used a Welches t-test ($\alpha = 0.05$), because it accommodates for unequal sample sizes and unequal variances among samples (table 1). Statistics were calculated in R (R Core Team 2013). We were unable to calculate survival rates, because the identification tags for many plants were damaged or removed

Table 1. Statistics and sample sizes to compare height development of ponderosa pine and juniper seedlings with and without drip irrigation.

Year	Ponderosa pine			Rocky Mountain juniper		
	*n**	*t*	*p*	*n**	*t*	*p*
2013	59 (8)	-0.52	0.613	139 (10)	-0.91	0.384
2014	51 (7)	-0.65	0.532	122 (10)	0.41	0.689
2015	47 (7)	-0.40	0.701	111 (10)	0.37	0.717

* Sample sizes for number of plants that received drip irrigation after 2013 are followed by the sample sizes for number of plants that did not receive drip irrigation (in parentheses).

by ungulates such that we could not distinguish between study plants and those that were planted solely for restoration. Statistics were calculated for the population of plants that retained tags throughout the study.

South-Facing Slopes

Sites on south-facing slopes consisted of three draws with severe erosion located within 0.6 km (0.4 mi) of each other. The draws received a significant amount of solar radiation and were mostly denuded of vegetation. Between mid-April and mid-May 2013, we planted the slopes with Rocky Mountain juniper (n = 135), antelope bitterbrush (*Purshia tridentata* [Pursh] DC.; n = 88), and mountain mahogany (*Cercocarpus ledifolius* Nutt.; n = 287).

Rocky Mountain juniper seeds were sourced as described previously. Great Bear Nursery (Hamilton, MT) grew the bitterbrush and mountain mahogany seedlings. Bitterbrush seeds were collected from northeastern Washington at approximately 1,800 m (6,000 ft) and were grown for 3 months. Mountain mahogany seeds were collected from the Rocky Mountains and were grown for approximately 1 year. Plant species were randomized across the site, woodchips were placed at their base, and exclosures and identification tags were

Figure 2. South-facing slopes included in the study were steep and dry. (Photo by Michael McTee, 2015)

installed at each plant following the same protocol used in the partially degraded site study (figures 2 and 3). Each plant was placed upslope of logs that were partially buried in the soil to create terraces for slowing soil erosion. Each log was 10 to 20 cm (4 to 8 in) in diameter and 100 to 200 cm (40 to 80 in) in length.

All plants were watered at the time of planting. Thereafter, plants were drip irrigated every 2 weeks at a rate of 3.8 L (1 gal) of water per hour for 4 to 8 hours.

Plant heights were measured at the time of planting and again each fall at the end of three growing seasons, following the same procedure used in the partially degraded site study. We pooled data from the three south-facing slopes for each species for statistical analysis. We compared differences in height development among species with a one-way Analysis of Variance, or ANOVA, with a Tukey's post hoc test (table 2). Statistics were calculated in R (R Core Team 2013).

Results

Partially Degraded Site

Junipers that were drip irrigated increased in height more during the first 2 years (49 and 52 percent, respectively) than during the following 2 years (11 and 14 percent, respectively; figure 4). Ungulate browsing on the leaders of some junipers likely influenced growth in the third and fourth seasons despite plants being protected by exclosures. Ponderosa pine seedlings grew less

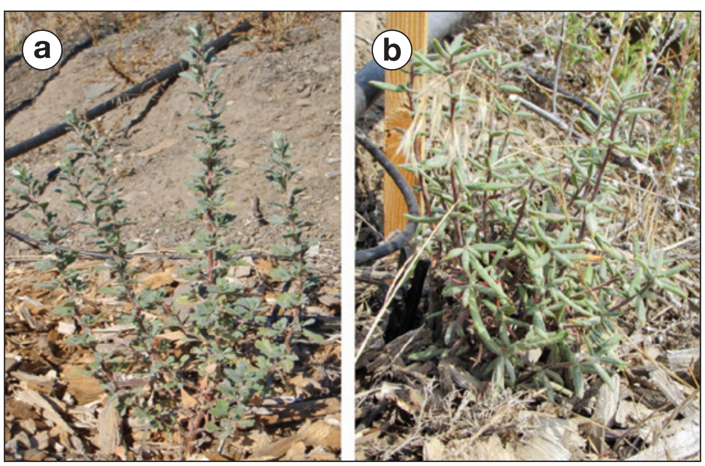

Figure 3. (a) Antelope bitterbrush, (b) mountain mahogany, and (not pictured) Rocky Mountain juniper were planted on south-facing slopes to assess height development. Wood chips were placed around each plant, followed by drip irrigation and an ungulate exclosure (removed for the photos). (Photos by Michael McTee, 2015)

during the first season (13 percent) than in subsequent growing seasons, in which they increased in height at least 30 percent from the previous year. After the assumed establishment period (2 to 3 years), drip irrigation did not significantly influence height growth of either species (figure 4, table 1).

South-Facing Slopes

All three species planted on south-facing slopes roughly doubled in height after three growing seasons (figure 5). Heights increased by 14 to 30 percent

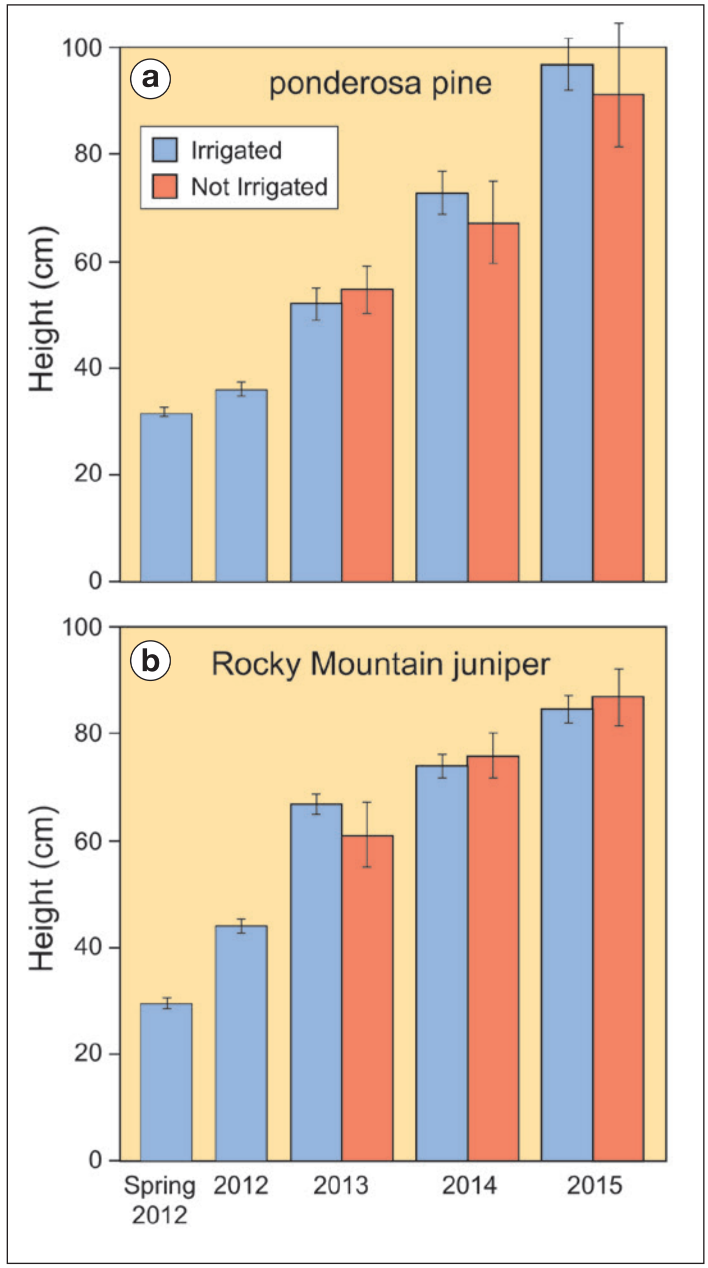

Figure 4. Mean heights of (a) ponderosa pine and (b) Rocky Mountain juniper during four growing seasons. All plants were drip irrigated in 2012. In 2013, we removed drip irrigation from a randomly selected subset of plants and found no irrigation effect thereafter. Error bars represent standard errors.

Table 2. Statistics and sample sizes to compare height development of bitterbrush, juniper, and mountain mahogany during four growing seasons.

Year	Sample sizes			F	P
	Bitterbrush	Rocky Mountain juniper	Mountain Mahogany		
Spring 2013	88	135	287	20.32	<0.001
2013	39	104	171	33.25	<0.001
2014	24	108	136	23.83	<0.001
2015	13	94	113	14.65	<0.001

during the first season, 5 to 14 percent during the second season, and 49 to 73 percent during the third season. Rocky Mountain juniper had an initial height greater than that of the other two species and retained its height advantage throughout the study, although the difference was no longer significant for bitterbrush in the third growing season (table 2). Mountain mahogany were taller than bitterbrush initially but not for the remainder of the study.

Discussion

At the partially degraded site, ponderosa pine had less relative height growth during the first season compared with height growth in subsequent growing seasons. Ponderosa pine grows long taproots that help young trees tolerate drought; therefore, resources during establishment were likely allocated more to the taproot than the aboveground tissues (Wier 2015). Drip irrigation did not influence the height growth of ponderosa pine or Rocky Mountain juniper, which suggests that the added effort and cost of irrigating these species may not be required once plants are established on the site and reach a certain level of maturity. Height measurements, however, do not reflect total biomass, which may have been influenced by irrigation and can affect long-term vigor and growth. The moderate compaction of the site may have inhibited plants from growing as vigorously as if they had been planted in less degraded soils (Ashby 1997).

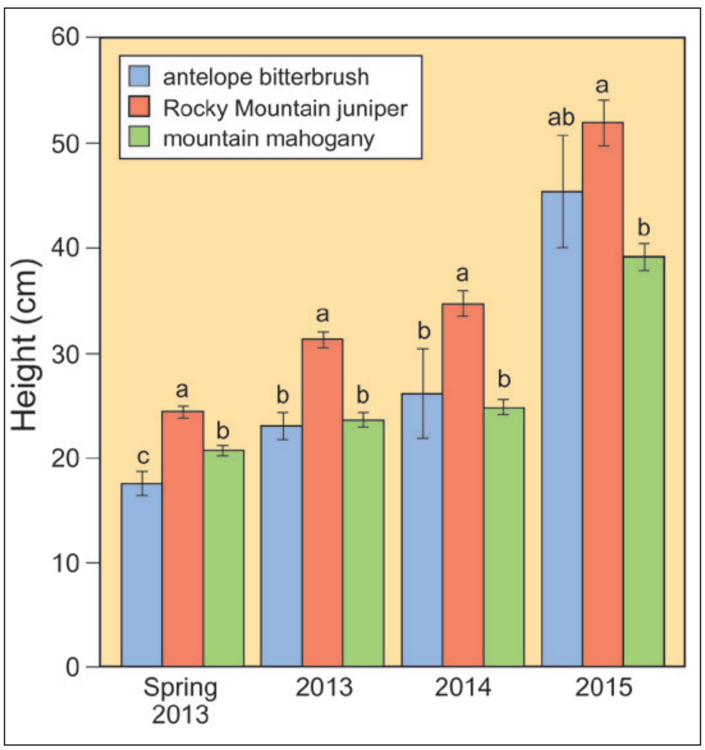

Figure 5. Mean annual heights of antelope bitterbrush, Rocky Mountain juniper, and mountain mahogany during three growing seasons. Error bars represent standard errors. Different letters above bars indicate statistical differences ($p \leq 0.05$).

South-facing slopes in the northern hemisphere receive more solar radiation than slopes of other aspects, resulting in warmer and drier conditions (Desta et al. 2004, Warren 2008). These conditions are unfavorable to plant colonization and establishment in semiarid climates, mainly due to water limitation (Bochet et al. 2009), so we irrigated all shrubs to aid in establishment (Bainbridge 2002). Surviving shrubs will eventually create conditions more conducive for the natural regeneration of other plants due to shading, soil stabilization, and erosion control (Gyssels et al. 2005). Larger plants can also serve as “shrub islands” that can be used for cover by wildlife and young plants (Padilla and Pugnaire 2006, With and Webb 1993). These isolated shrubs may also be a source of seeds in areas where seeds are scarce and natural colonization is rare. Bochet et al. (2009) found that plants cease to colonize south-facing slopes at slope angles greater than 40 degrees in a semiarid ecosystem in eastern Spain. At our south-facing study sites, the slope angles ranged from 5 to 35 degrees, suggesting that some sites may be near the threshold for natural establishment.

Overall, these studies give restoration practitioners some practical data regarding performance of common restoration species in semiarid rangelands of the Intermountain West. Degraded sites within these landscapes present additional obstacles that may be overcome by increasing management efforts, such as by installing drip irrigation, ungulate exclosures, or structures that control erosion. Ultimately, plant success will depend on many factors that may be unique to the site and the timing and patterns of weather during plant establishment.

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