Weed Technology. 2004. Volume 18:1213–1215

Symposium

# Microclimatic Constraints and Revegetation Planning in a Variable Environment[1]

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**Abstract:** Soil water availability is a primary determinant of successful plant establishment on western rangelands. Two major factors that determine water availability are seasonal and annual patterns of precipitation and the presence of competitive annual weeds. Seedbed microclimate and germination response models can be used to evaluate alternative management treatments and plant materials and to incorporate medium- and long-term weather forecasts into real-time management planning. To take full advantage of these tools it is necessary to separate short-term soil stabilization and longer-term biodiversity and restoration objectives. Emergency rehabilitation policies prioritize establishment of plants that will both stabilize the soil and compete successfully with invasive weeds. Weather forecast information and modeling may be more useful to longer term restoration planning where revegetation and weed control actions can be deferred to coincide with a favorable microclimatic forecast.

**Additional index words:** Big squirreltail, bluebunch wheatgrass, *Bromus tectorum* L., cheatgrass, *Elymus multisetus* (J. G. Smith) M. E. Jones, emergency rehabilitation, invasive weeds, *Pseudoroegneria spicata* (Pursh) Löve, restoration.

## INTRODUCTION

Millions of acres of sagebrush–bunchgrass rangeland in the Intermountain western United States have been invaded by nonnative annual weeds such as cheatgrass (*Bromus tectorum* L.). Cheatgrass competes aggressively with seedlings of native grass and shrub species for limited water and nutrient resources in the fall, winter, and spring (Harris and Wilson 1970; Melgoza et al. 1990; Novak and Mack 2001; Wilson et al. 1974). Cheatgrass-dominated systems are characterized by frequent recurrence of wildfire and are resistant to management actions designed to return them to a more desirable ecological state (Brandt and Rickard 1994; Knapp 1996; Young and Longland 1996).

Restoration practices in cheatgrass-affected systems have generally been limited to emergency rehabilitation procedures in the year after wildfire, the primary objective of which is soil stabilization (Bureau of Land Management 1999; Richards et al. 1998). Species selection for fire rehabilitation has historically included a number of highly productive and competitive nonnative grass species (Asay et al. 2001; Call and Roundy 1991). Current policies include additional objectives for plant community restoration and encourage the use of native plant materials in postfire revegetation planning. The high level of climatic variability in both time and space and presence of highly competitive annual weeds may preclude simultaneous achievement of both soil stability and native plant–biodiversity objectives in most years (Bakker et al. 2003; Call and Roundy 1991; Evans et al. 1970).

The purpose of this article is to review the nature of weather variability in these systems, assess the effect of microclimatic variability on establishment success of native plant and annual weed species, and discuss management opportunities for optimizing both burn rehabilitation and native plant restoration objectives.

## SEEDBED MICROCLIMATIC VARIABILITY AND GERMINATION RESPONSE

Seeding guides for Intermountain rangelands generally acknowledge the importance of climate in the form of tables that list species suitability as a function of mean annual precipitation (Jensen et al. 2001). Unfortunately, the microclimatic constraints for germination and seedling establishment are much more restrictive than the longer term climatic requirements for mature plant communities (Call and Roundy 1991). Figure 1 shows the high level of variability in both annual and early-spring

[1] Received for publication December 30, 2003, and in revised form March 5, 2004.

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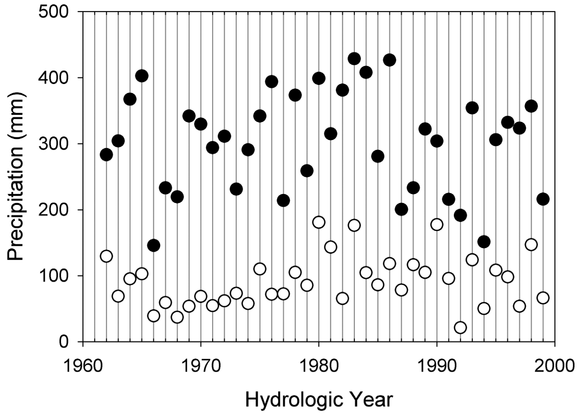


*Figure 1.* Total precipitation during the hydrologic year (October 1 to September 30; closed circles) and during the March to May establishment period (open circles) in the Snake River Plain, south of Boise, ID, for the period 1962 to 1999.

precipitation for the period 1962 to 1999 in southwestern Idaho.

Atmospheric inputs of precipitation, solar radiation, temperature, humidity, and wind affect soil temperature and water availability in the seedbed. Hardegree et al. (2003) used weather and soil data from the Orchard Field Test Site in southwestern Idaho to calibrate the SHAW microclimatic model (Flerchinger and Saxton 1989a, 1989b) and estimated soil temperature and water at seeding depth for every hour between October 1, 1961, and September 30, 1999. Hourly microclimatic estimates were used as inputs into a hydrothermal germination response model for two seed lots each of bluebunch wheatgrass [*Pseudoroegneria spicata* (Pursh) Löve], big squirreltail [*Elymus multisetus* (J. G. Smith) M. E. Jones], and cheatgrass. Hardegree et al. (2003) discuss the methodology and assumptions inherent in this model that produced relative estimates of potential germination rate and an integrated index of relative establishment potential for each seed lot as a function of planting date. Their data confirmed previous studies that showed the relative potential performance of cheatgrass to be consistently higher than those for the two native grass species (Hardegree 1994a, 1994b; Hardegree et al. 2003). Hardegree et al. (2003) also quantified the probabilities of a favorable seedbed microclimate, the relative favorability of seedbed microclimate in early spring, and the relative responsiveness of these species to precipitation received during the March to May establishment period.

## MANAGEMENT IMPLICATIONS

Cheatgrass is known to germinate and establish rapidly in the fall, winter, and spring and to compete strongly with native grass and shrub seedlings for available moisture and other soil resources (Harris and Wilson 1970; Knapp 1996; Melgoza et al. 1990; Wilson et al. 1974; Young and Longland 1996). The ecological consequences of rapid germination are exacerbated by prolific seed production in this species (Humphrey and Schupp 2001). The data in Figure 1 and the microclimatic probabilities established by Hardegree et al. (2003) demonstrate, however, that seedbed water can be a limiting factor in many years regardless of the level of cheatgrass competition.

Emergency fire rehabilitation plans emphasize soil stabilization as the primary resource objective (Bureau of Land Management 1999; Richards et al. 1998). Native species restoration is acknowledged as desirable but may be unobtainable because of the lack of seed, drought, and weed competition (Call and Roundy 1991; Richards et al. 1998). The number of acres needing emergency fire rehabilitation is highly variable from year to year, and in a big fire year, native seed may be unavailable (Richards et al. 1998). Indeed, cheatgrass control measures might exacerbate erosion problems in a poor precipitation year if seeded species (native or nonnative) have poor establishment. Current state and transition models for rangeland restoration acknowledge that there are perhaps a limited set of potential trajectories for moving between undesirable and desirable vegetative states (Briske et al. 2003; Westoby et al. 1989). These limitations require definition of realistic goals when establishing rehabilitation and restoration-planning objectives (Ehrenfeld 2000; Hobbs and Norton 1996; Jones 2003). In most years, it may be prudent to use more easily established, nonnative species for soil stabilization after wildfire (Asay et al. 2001) and to address biodiversity and restoration objectives in a subsequent year when climatic conditions are amenable.

Knowledge of weather and climate variability may be more useful for restoration planning during nonfire years. Westoby et al. (1989) noted that many transition pathways between alternative states require the occurrence of a specific and perhaps infrequent series of climatic events. Even low-resolution weather forecasts would increase the probability of successful native plant establishment if seeding decisions in the fall could be based on the anticipation of favorable conditions of seedbed microclimate in the subsequent winter and spring. Weather forecasts could be used to initiate contingency plans in areas that have been previously identified for restoration and for which premanagement logistics of equipment, personnel, and plant materials are in place

(Bakker et al. 2003; Westoby et al. 1989). Separation of restoration-planning objectives from the wildfire cycle also simplifies the problem of predicting management needs for native germplasm (Richards et al. 1998). Historical climate records provide a relatively stable estimate of the probability of favorable establishment years that could be used to predict acquisition and storage requirements for native seed.

Weed competition and drought considerations have previously served as justification for use of nonnative plant materials or weed control strategies as a generic prescription for rangeland restoration (Asay et al. 2001; Call and Roundy 1991). Additional field research is probably not necessary to confirm the relative competitiveness of nonnative plant materials in arid and semiarid rangeland systems (Asay et al. 2001). Additional research, however, should be conducted to determine the relative feasibility of transitioning from cheatgrass to a native-dominated system through the intermediate step of a nonnative perennial plant community. Nonnative perennial grasses have been noted to specifically reduce annual weed seed in the seed bank (Buman et al. 1988; Evans et al. 1970). Bakker et al. (2003) have subsequently used herbicides to reduce competition from nonnative perennial grasses. Current restoration-planning strategies tend to focus on the, perhaps more difficult, direct transition between a cheatgrass and native plant system state.

The stochastic nature of weather variability will require adoption of new concepts for evaluating revegetation and restoration success. The major difficulty at this time is the availability and use of weather-forecasting technology. Long-term weather forecasts in the Intermountain West are often merely a synoptic description of historical weather patterns and are not based on physical or empirical prediction of future weather conditions. It may be possible, however, to use historical weather and seeding data to construct economic models to assess the potential long-term benefits of adopting forecast or modeling technology in rangeland restoration planning.

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