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Germination Syndromes and their Relevance to Rangeland Seeding Strategies in the Intermountain Western U.S.

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Sagebrush/bunchgrass rangelands are increasingly dominated by invasive annual grasses that proliferate after wildfire in lower elevation plant communities. In addition to a reduction in resource values and services, invasive annual grasses increase the frequency and intensity of dangerous wildfires, alter nutrient cycles, and reduce site productivity in ways that may preclude restoration to historical levels of compositional and functional diversity. Additional pressures from a rapidly warming climate and changing precipitation distribution could lead to widespread extinction of locally adapted ecotypes as native plant communities have insufficient time to evolve or to migrate in an increasingly fragmented landscape. Post-fire rehabilitation and restoration practices in the Intermountain West are predominantly implemented in the fall between early October and the onset of frozen soil conditions in early winter. The specific time of planting at a given location depends on random factors associated with the logistics of contracting, travel requirements, personnel, equipment, and seed availability.

Fall seeding has historically been recommended in this region to get the seeds in the ground before the primary period of rainfall in the winter and spring. This rationale, however, oversimplifies the relevant processes affecting the transition of these species through multiple life-cycle phases, and in any case, has not resulted in an acceptable probability of restoration success over the last 80–100 years of implementation. A potential bottleneck to seedling establishment may be post-germination mortality during winter freeze events. A more comprehensive understanding of plant life cycles and their interaction with seedbed microclimate may yield insights into the requirements for successful seedling establishment in the highly variable and rapidly changing climate of the western US.

Short-term, local field experiments cannot survey the full range of seasonal and annual variability in weather at any one location. They can, however, be expanded by modeling seedbed microclimate and simulating potential seed germination and emergence under a broader range of historical weather conditions. This approach has been used to examine the seasonality of seedbed favorability for germination, alternative germination models for more accurate estimation of potential field response, and to explore the nature of environmental variability in germination rate and seedling mortality after germination.

In this issue of *Rangeland Ecology & Management* (Volume 73; issue 2), a group of researchers used moisture/temperature simulation modeling to predict the cumulative germination response of 13 rangeland-grass seed lots had they been planted at a field site in southeastern Idaho during any week of the growing season in the previous 57 years. Specific objectives were to evaluate the seasonal and annual variability in cumulative germination response of these seed lots, and to determine alternative germination syndromes that might yield insights into planting-date and planting-year effects on restoration outcomes.

They found that with the highly variable pulse of seedbed favorability and pre-emergent seedling mortality, the ability to grow from seed to germinated-seed to emerged-seedling is relatively fixed and has low probabilities for individual seed lots after single planting events. Two strategies, however, could be used to improve the overall probability of successful seedling establishment from a given seed mix in most years. First, consistently planting as late in the fall as possible, and second, intentional diversification of germination rate within the seed mix. Diversification of within- and between-population germination rates can increase the probability that some seeds are always available to take advantage of pulses of germination favorability through the fall, winter and early spring. This is a departure from many previous seed studies that have recommended unidirectional modification of seed-germination rate to either germinate faster or slower to avoid specific germination hazards. Diversification

of the seed mix can be accomplished by using multiple seed lots of the same species, increasing the number of species in the seed mix within different functional groups, or using artificial treatments to expand the range of germination rate within a given seed population. These recommendations, however, only address the probability of increasing the success of early life-cycle transitions and numerous other abiotic and biotic barriers may prevent successful plant community establishment. Longer term goal achievement is likely to require persistent iterative management to maintain a positive trajectory toward an acceptable level of functional and compositional diversity.

Nearly all this article was taken directly from the manuscript that can be read in its entirety in *Rangeland Ecology & Management* 73 Issue 2.

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