The Importance of Seed Germination in Rangeland Research

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Human fascination with germination dates back thousands of years when agriculture was developed. The Egyptians viewed germination as a form of resurrection as the plant came back to life. Many bible scriptures reference the miraculous potential of a geminating seed. At its most basic definition germination is the active growth of an embryo. In modern times the study of germination can focus on many aspects of this complex physiological process. In the field of rangeland research and management this seemingly small biological activity is at the heart of successful management. From weed suppression to fire rehabilitation seeding, understanding germination is key. The USDA, Agricultural Research Service (ARS)/ Great Basin Rangelands Research Unit, Wildland Seed Laboratory, located in Reno, NV, has been studying seed germination for the past 40 years. The wildland seed laboratory has collected, processed, and quantified germination characteristics of hundreds of native and introduced rangeland plant populations. The research laboratory uses multiple large incubators to test seed germination at multiple temperatures representative of Great Basin seedbed temperatures. By mimicking the day and night fluctuations of seasonal temperature regimes we are able to determine optimal germination temperatures and seasons for a particular species. For each standardized test 5,500 seeds are used. Moving seeds in germination petri dishes from warm to colder incubators during the day and night allows us to test 55 separate constant and fluctuating 24 hour temperature regimes. For example, one set of seeds may be in 8 hours at 68F during the day and then 16 hours at 41F for the night. By testing all 55 different temperature combinations from 32F to 104F (9F increments) we can provide a standardized germination temperature profile (Figure 1). Generally, successful plants often have a wider range of germination temperatures. However, to germinate is not always in a seeds best interest. Germinating at non-optimal times (i.e. cold or dry seasons) can lead to seedling death. Nature in its wondrous ways though has provided mechanisms for a seed to avoid such a fate. Seeds can maintain a state of dormancy where germination only occurs after environmental cues initiate it. The constantly evolving relationship between a seed and its environment makes the study of germination mysterious and ever-changing. There has probably been no species studied more for germination in the Great Basin than cheatgrass. This exotic invasive annual weed has contributed to the loss of millions of acres of habitat, by providing fine-textured early maturing fuels that increase the chance, rate, season and spread of wildfires. This fuel is coupled with its strong competitive inherent ability to limit the recruitment of native plants. Like many annual plants it has a "bet hedging" seed strategy where seeds can be non-dormant and germinate after the first rain or they can be dormant, where even with moisture, the seed will not germinate. Seed dormancy insures that there will be seed carried over in the soil to the next year or longer, and in the case of cheatgrass, can lead to 100s of seeds per square foot in the soil seed bank (Figure 2). We tested cheatgrass seed bank densities on more than 100 separate locations across the Great Basin in which cheatgrass seed bank densities ranged from 0 to 1,272/ft², and averaged 252 cheatgrass seeds/ft². The ability of cheatgrass to build persistent seed banks allows this species to "mine the site" until the right opportunity comes along to dominate the site. Seed dormancy also mitigates the risks of seedling death in highly variable environments that can go from warm to cold and wet to dry quickly. And as many of us in the arid Great Basin know, "If you don't like the weather wait 10 minutes or walk a mile and it will change". Cheatgrass is a clever plant that has developed increased "bet hedging" (seed dormancy) in populations from "riskier" habitats. Populations from drier hotter environments, like salt deserts, show greater seed dormancy, quicker time to flowering, and greater seed production, than populations from less risky, wetter, and cooler environments. Some annual plants like Russian thistle and tumble mustard take advantage of highly variable weather events. These plants do not express seed dormancy and will germinate rapidly after any summer rain. A fence buried in Russian thistle in the fall is often the result of this event, and an unfortunate common occurrence in the Great Basin. Even though summer months are hot and dry it is an advantage for poor competitors like Russian thistle and tumble mustard to germinate after summer rains, because most strong competing winter annuals like cheatgrass have completed their life cycle by this time. Unlike annuals, most native perennial grasses do not rely on seedling establishment every year nor do they build seed banks that persist for multiple years. However, like most things in nature there are exceptions to the rule. Indian ricegrass, a native perennial bunchgrass, has the inherent

Figure 2. Cheatgrass seed after the 2012 Rush Creek Fire in northeastern California and northwestern Nevada. This fast moving cheatgrass fueled wildfire left most seeds unharmed making seeding efforts after the fire ineffective.

GERMINATION PROFILE

Warm Period Temperature °C

Cold Period Temperature °C	0	2	5	10	15	20	25	30	35	40
	Percent Germination									
0	48	62	60	83	87	87	89	79	42	42
2		61	62	83	84	74	86	83	70	48
5			70	80	89	87	92	93	79	53
10				88	93	86	93	91	76	77
15					92	94	93	92	86	67
20						91	94	92	89	74
25							85	89	73	77
30								75	68	72
35									29	31
40										24

Figure 1. The USDA/ARS/Great Basin Rangelands Research Unit Wildlands Seed Laboratory houses 15 large incubators for germination tests. Germination is measured in 255 petri dishes weekly for each germination test for four weeks. The final data is presented in a germination profile providing the germination percent for 55 different day (warm) and night (cold) temperature regimes.

ability to produce a variety of phenotypic seeds from big and brown, to small and naked with no covering. The naked seeds are not dormant, but the dark brown seeds are strongly dormant in order to maintain a seed bank. In favorable years the dormant seeds can break dormancy, germinate and provide a flush of new seedlings. Many hard seeded native shrubs will exhibit strong seed dormancy and maintain seed banks too, unlike the small seeded sagebrush which has minimal seed banks. This makes sagebrush seeding efforts critical to restore plant populations after a fire. Sagebrush seedlings have a modified root with a barbed tip to anchor the small seedling to the soil (Figure 3). It is important to avoid seeding big sagebrush on top of snow, because it often does not allow the radicle to anchor to the soil. Good seed and soil contact is crucial for germination and seedling development. There are mechanisms that can decrease seed dormancy such as stratification, where seeds germinate after being exposed to cool moist conditions. From a plants standpoint, this insures seeds will germinate during cool wetter months. For example, antelope bitterbrush, an important shrub species, sets seed in July. We actively seed this species in September and October, and our research has shown that the vast majority of this seed is germinated by mid-December even though seedling emergence is not until early March. This is important information to know as many antelope bitterbrush land management seedings do not take place until late December to early March. Late winter/early spring seedings are insufficient for stratification requirements. Seeding efforts should occur in the fall prior to the onset of winter to allow adequate time for seeds to stratify in the soil, break dormancy and germinate. Seeding later into winter/spring (Dec – Feb) often does not achieve this. Germination has important plant material development implications too. When selecting plants for rangeland rehabilitation seeding, it is desirable for a plant to exhibit cold germination to ensure early root development. Successful rehabilitation plants such as crested wheatgrass germinate at colder temperatures than native plants such as squirreltail, which are more difficult to establish. This earlier germination of crested wheatgrass results in 35x more root development than later germination species such as squirreltail, which is one of the reasons that crested wheatgrass experiences higher success in seeding efforts.

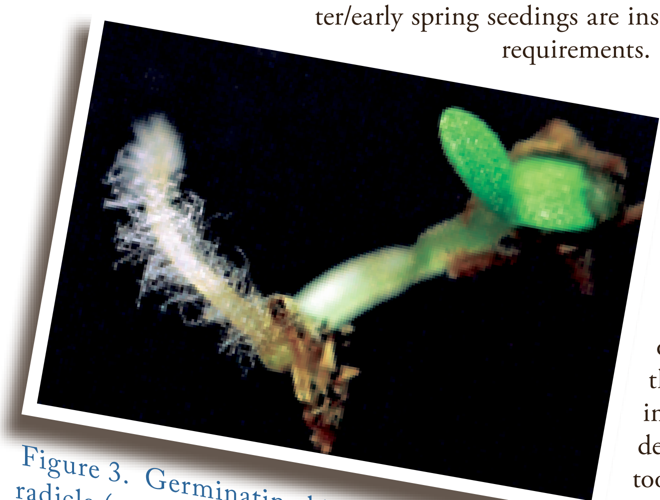

Figure 3. Germinating big sagebrush seed with radicle (embryonic root). The hairs serve to anchor the seedling to the soil surface and penetrate the soil to uptake moisture.

One of the most valuable tools for reducing cheatgrass densities, in an effort to more effectively manage plant communities, is the use of herbicides. Primarily, soil applied herbicides are used where all newly germinated seedlings will be killed over a one-year fallow period. This depletes the weed seed bank so that the following year desirable plants can be established with less competition from weeds. For the herbicide treatment to have an optimal effect it is necessary to have a high degree of germination during the herbicide activity period, which makes understanding and predicting germination important. Wildfires, if hot enough, can kill undesirable weed seed banks and provide rangeland seeding opportunities. Unfortunately, once a habitat has converted to cheatgrass dominance, the reoccurring fast moving wildfires are not hot enough to kill most cheatgrass seeds (Figure 2) and cheatgrass continues to dominate the site. A policy of resting these sites from grazing after fires without successful rehabilitation practices only further promotes cheatgrass. Immense unchecked seed production following such management decisions insures years of persistent cheatgrass seed banks.

Many physical properties of the seed can affect germination. Hard seed coats inhibit moisture uptake and require scarification, where the seed coat is partially broken to allow the seed to imbibe moisture.

Some seeds, often mustards, can produce a mucilage layer that promotes water uptake. The sticky mucilage can also aid in dispersal by sticking to animals or other objects (Figure 4). Seed hairs and root radicle modifications can also improve moisture retention, surface soil attachment and wind dispersal. Some seed dispersal appendages, such as the hairs on winterfat seed, make rehabilitation seeding efforts very difficult because the seed cannot readily pass through seed drills. Applying the knowledge of the physical seed and germination properties can improve management efforts in order to preserve a sustainable rangeland resource.

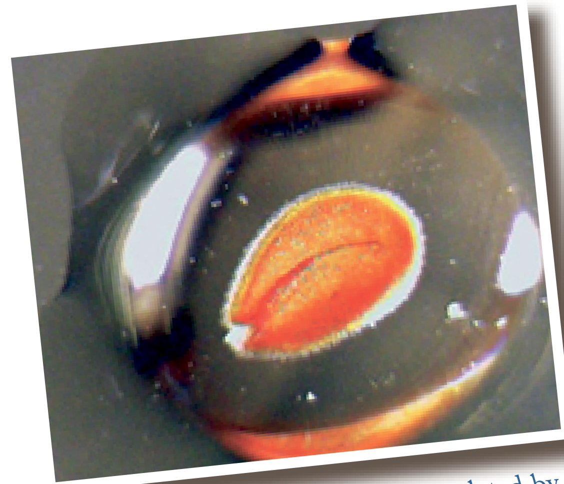

Figure 4. A shieldcress seed encapsulated by a moisture conserving mucilaginous layer. The sticky mucilage can also aid in dispersal by adhering the seed to animals.

George Washington said "bad seed is a robbery of the worst kind: for your pocket-book not only suffers by it, but your preparations are lost and a season passes away unimproved". This statement holds many truths for rangeland management. Poor seed choice and lack of understanding germination principles can lead to management failures in a time when rangelands are threatened more than ever. Making sound scientific decisions is the best way to preserve the natural rangeland resource that is important to so many. For to know the seed is to know the future.

The Argicultural Research Service, Great Basin Rangelands Research Unit is currently working on an online germination data resource that will provide the germination profiles for all tests conducted by the lab. It can be found at www.ars.usda.gov/pwa/gbrr/seedlab