Soil • Plant • Water • Seed

SOILS NEWS

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Water Potential: The Key to Successful Seed Priming

—Dr. G. A. Harris

The increasing interest in understanding and controlling germination rates and improving seedling stands and yields has inspired investigation into the physiological principles controlling these reactions.

Water is the most important physiological factor for seed germination. Water potential (Ψ) is a measure of water's availability to participate in processes. Water molecules flow through substrate pores (in soil, seeds, etc.) from high water potential sites to low water potential sites to reach equilibrium within seed environments. Water potential ranges from zero megapascals (Mpa) in pure water (high Ψ) to -100 MPa for air dry seeds (low Ψ).

In seed priming the water potential is controlled by manipulating either the matric potential or the osmotic potential. Osmotic potential is the reduction in the energy of water caused by its dilution with solutes such as salts and sugars. The matric potential results from a reduction in the energy status of water due to adsorption on cell walls, proteins, and soil colloids.

Why is it so important to know Ψ in seed priming?

Seeds germinate when Ψ in the seed reaches a critical physiological level (usually between 0 and -2 MPa). Seeds with

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Inside

Seed Longevity in Storage is Enhanced by Controlling Water Activity—*Dr. G. S. Campbell*

Water, temperature, and oxygen are the three environmental factors are of fundamental importance in determining the longevity of stored seeds. Orthodox and recalcitrant seed groups respond differently to water (Roberts, 1973). Orthodox seeds can be dried to low water contents without damage. Recalcitrant seeds suffer desiccation mortality if they dry below some critical moisture level. This application note focuses on water in orthodox seeds.

Measuring seed moisture.

The state of water in seeds relates to the amount of water in the seed and the energy

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Germination

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permeable seed coats usually go through three germination phases: **(1)** imbibition, when water flows through the seed coat into the embryo, leading to **(2)** the activation phase, when stored seed hormones and enzymes stimulate physiological development leading to **(3)** growth of the radicle, ending the germination phase. Water movement into dry seed during the imbibition phase is at first rapid but slows as Ψ of the seeds approaches Ψ of the environment. If imbibition is too rapid damage to hydrating cells often occurs.

Seed priming can be successfully accomplished only during the activation phase. Figure 1 shows a theoretical example of germination at a series of high Ψ levels. Germination at high Ψ occurs too quickly to allow priming opportunity. By allowing the mixture to come to equilibrium at lower Ψ levels, phase II is lengthened, allowing priming activities to proceed.

Seed priming techniques.

Priming reduces germination time and improves stand and percentage germination. Osmotic priming uses chemicals such as polyethylene glycol, glycerol, and mannitol to reduce osmotic potential. Matric seed priming controls Ψ by reducing the matric potential of the water through adsorption on particle surfaces by mixing seeds with specialized vermiculite compounds (Zonolite), Celite, or Micro Cel.

Priming seeds.

Matric priming requires careful mixing of seed

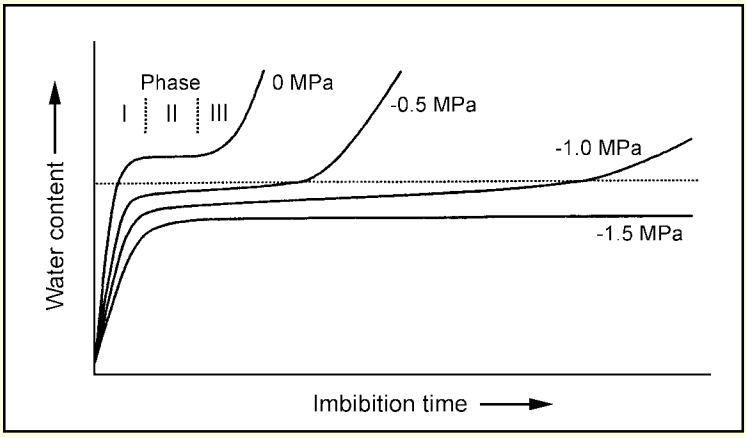
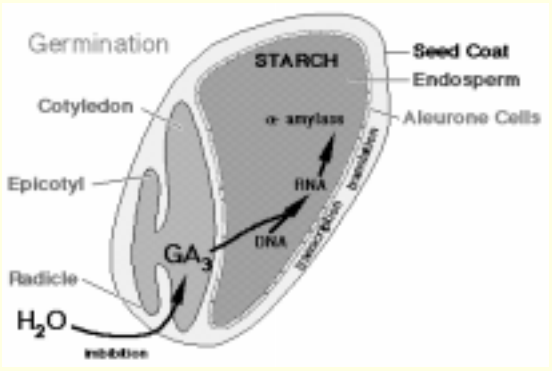


Figure 1. *Time courses of seed Ψ during three phases of germination. Imbibition at reduced Ψ lowers seed water content, extends the length of phase II, and delays entry into phase III. Radical emergence and growth will occur if the water content exceeds a critical level indicated by the horizontal dotted line.*



■ *Presence of water is known to be the most important physiological factor needed to bring about seed germination.*

with the priming medium and water. Water is added to raise Ψ and start the imbibition phase. A waiting period allows water to diffuse throughout the mix and achieve Ψ equilibrium throughout. The approximate water content needed in the priming medium to reach the correct water potential can be established by making a moisture release curve. *(see App. Note # XXX)*

Measuring Ψ in seed priming programs.

Decagon's WP4 Dew Point PotentiaMeter provides accurate, rapid, and convenient water potential data for the mixture and indicates the desired activation phase. Analysis times are 5 minutes or less for most samples. The WP4's unusual speed allows on-line monitoring of Ψ during practical operations. Just fill the sample cups, place the cup in the sample drawer, and turn the knob to start the analysis. Results appear directly in the display and can be downloaded to a computer. Measurements in the critical Ψ range of 0 to -2.5 MPa are accurate within ±0.1 MPa.

The future looks bright for innovative research and practice in this field, and the opportunity for success appears to be great. Availability of research and measurement instrumentation offer important advantages for immediate progress. ■

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June 2000
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Texas A&M
Southwest Research Institute
New Mexico State
New Mexico Tech
Sandia National Labs

This Fall-
Southern California Tour
Contact Bryan@decagon.com for a product demonstration when we visit California.

WP4 Potentimeter measures water potential—without waiting; a sample reading in under 5 minutes —without range limitations; 0 to -40 Mpa —without hassles; just load and read.

Operating environment: 5 to 43°C, 20 to 85% relative humidity.
Sensors: 1. Infrared sample surface temperature. **2.** Cooled mirror condensation dew point.
Power: 110V or 220V AC, 50/60Hz.
Display: 20 x 2 alphanumeric dot-matrix LCD with backlighting.
Accuracy: 0.1MPa
Range: 0 to -38MPa
Resolution: ±0.001.
Interface cable: StandardsRS232 serial cable included.
Communications: 9-pin D-subminiature, RS232 compatible, 8-data bit ASCII code, 9600 baud, no parity, 1 stop bit.
Weight: 3.2 kilograms.
Shipping Weight: 5.2 kilograms.
Case material: Powder coat aluminum.
Sample dish capacity: 15ml full (7ml recommended).
Enclosure size: 25.4 x 22.8 x 11.4cm.
Fuse: 2A. Fast-Blo.

WP4 Potientiameter
For Soils Applications

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509-332-2756
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status, expressed as water activity, equals the relative humidity of air that is in moisture and temperature equilibrium with the seeds.

The water potential is uniquely related to the water activity through the equation:

$$\Psi = \frac{RT}{M_w} \ln a_w$$

Eqn. 1

where R = universal gas constant, T = Kelvin temperature, and Mw = molecular mass of water.

Water activity and water potential are measured by equilibrating a seed sample in a sealed chamber and measuring the relative humidity of the head space. Water activity equals the relative humidity, and the water potential is computed from eq. 1. Decagon's AquaLab Series 3 water activity meter equilibrates approximately 5 grams of material in a sample chamber and determines the water activity from the dew point temperature of the air in equilibrium with the sample. The measurement takes about five minutes.

The Isotherm

A unique isotherm describes the relationship between water content and water activity for a particular seed sample and species (Roberts and Ellis, 1989). It doesn't matter whether water content or water activity is measured, since the isotherm for a particular sample allows the other to be inferred. If no isotherm is available, then the variable that best represents the process of interest must be measured.

Which measure is best for predicting seed longevity?

Water content has been used to describe the effect of moisture on seed viability, and to make recommendations for seed storage conditions or maximum longevity. The logarithmic relationship between longevity and seed water content must be determined for each species (Roberts and Ellis 1989). However, the relationship between water activity and longevity is linear and similar from species to species (Roberts and Ellis 1989). Describing seed water status in terms of water activity eliminates specific testing of each seed lot, and a simple water activity measurement quickly provides information to indicate whether seeds are at optimum moisture for storage.

Water activity has the distinct advantages of being directly and unambiguously related to seed longevity.

Complications from seed coats

Water content measurements on coated seeds is of little value in determining whether a seed drying operation meets a specification because seed and coatings can have the same water activity but different water contents. But water activity, the driving force for moisture migration, is the same in the seed and the coating and can be easily measured on both. Seeds and their coatings can simply be dried to the water activity specified for safe storage.

Conclusion

Seed moisture status can be described in terms of water content or water activity. Water activity has the distinct advantages of being directly and unambiguously related to longevity, and critical points are similar for different species. ■

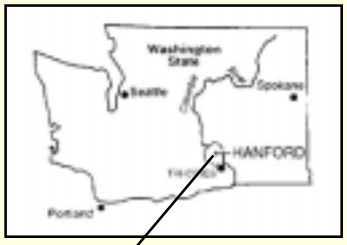
Table 1. Water activity, water potential (eq. 1), and water contents of rape (*Brassica napus*) and wheat (*Triticum vulgare*).

Water Activity	Water Potential (Mpa)	Rape Water Content (g/g)	Wheat Water Content (g/g)
0.10	-314	0.031	0.060
0.20	-219	0.039	0.080
0.30	-164	0.045	0093
0.40	-125	0.052	0.106
0.50	-94.4	0.060	0.120
0.60	-69.6	0.069	0.132
0.70	-48.6	0.080	0.147
0.80	-30.4	0.093	0.163
0.90	-14.3	0.121	0.215

Water content data are from Roberts (1972).

References Roberts, E.H. 1972. Viability of Seeds. Chapman and Hall, London

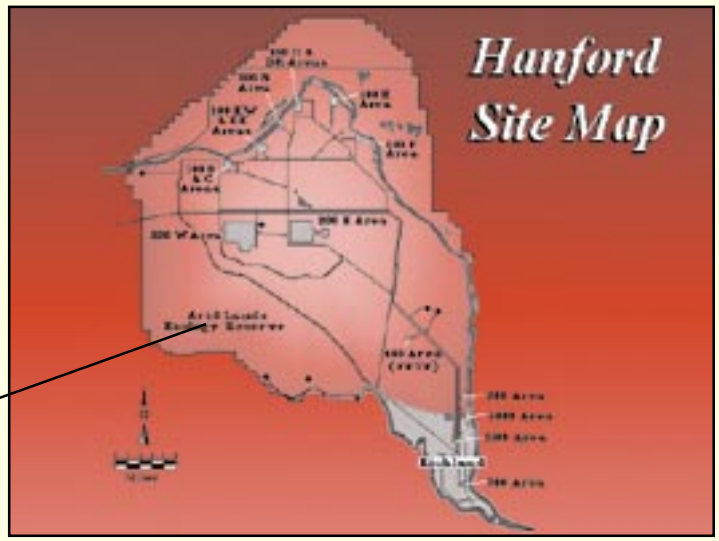
Washington State, USA



Hanford

Environmental restoration on the Hanford Nuclear Reservation

by Robin Durham.



Environmental Restoration Disposal Facility (ERDF)

Hanford— 560 square miles of shrub steppe, sand and sagebrush located on the Columbia River in southeastern Washington State. The Hanford Site is managed by the U.S. Department of Energy, the successor agency to the Atomic Energy Commission. As a plutonium production complex, Hanford played a pivotal role in the nation's defense for more than 50 years beginning in the 1940's with the creation of the site as part of the Manhattan Project. Currently, Hanford is engaged in the world's largest environmental cleanup project, with many challenges to be resolved in the face of overlapping technical, political, regulatory, and cultural interests.

IN THE SEMI-ARID steppe region of south-central Washington, the Department of Energy (DOE) encourages programs that support young scientists while conducting research in support of environmental restoration on the Hanford Nuclear Reservation. We asked Robin Durham, a graduate student in restoration ecology from Washington State University, to tell us a bit about her research and how she has been able to use instruments such as our WP4 Dewpoint PotentiaMeter on her projects:

Projects on Hanford such as the Environmental Restoration Disposal Facility (ERDF), and Tank Waste Remediation System (TWRS), have led to the decline of big sagebrush *Artemisia tridentata Nutt.* habitat in recent years. Mature big sagebrush stands are considered an important ecological resource on Hanford where current regulations and require that either restoration or mitigation be conducted when these habitats are damaged or the habitat is destroyed. Both the ERDF and TWRS projects have resulted in the need to mitigate the loss of habitat on a large scale, planting nearly 100 thousand big sagebrush plants each year since 1998.

In 1998, I was provided an opportunity through the ERDF mitigation project to study the survival and growth of big sagebrush seedlings. I chose to study the survival and growth of big sagebrush seedlings across some varying soil textures (sandy vs. silt loam) and community compositions (alien- vs. native-dominated vegetation) on Hanford.

The landscape provided microclimates and variable physical characteristics that I hope will contribute toward a linkage between the studies of restoration and landscape ecology. When the results of survival data showed significant differences across the

> “I have used other techniques to develop moisture release curves that required a lot of training and experience to achieve sometimes marginal results. I was pleased with the WP4 performance because of its ease of use and range of measurement.”

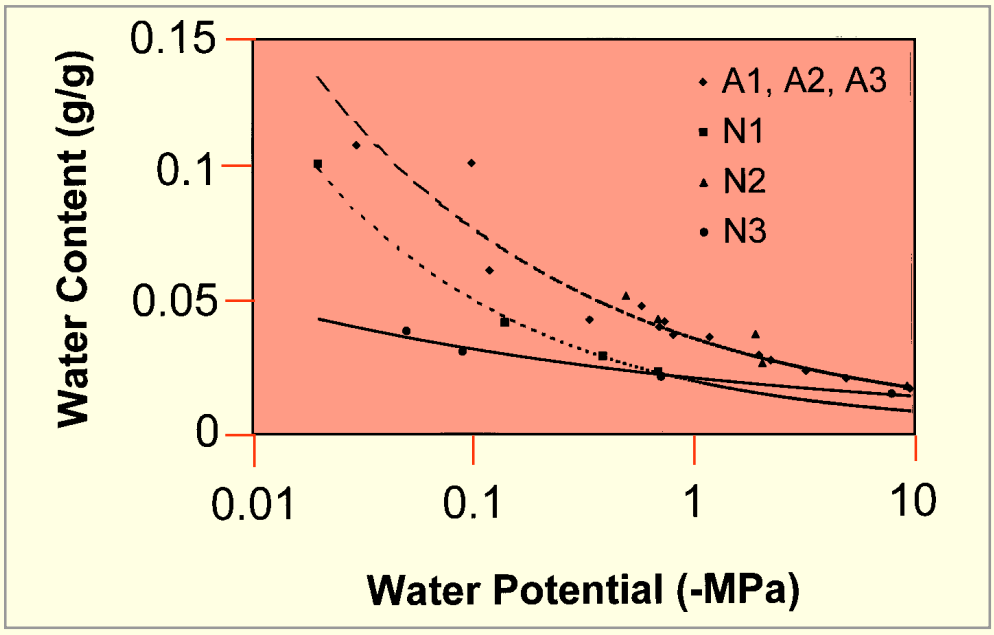


Figure 1. *Soil moisture release curves for six sandy locations along the lower Cold Creek valley. Symbol A represents three combined cheat-grass (Bromus tectorum) dominated plots. Symbol N represents plots dominated with Sandberg's bluegrass (Poa secunda).*

sandy locations, I chose to take a closer look at soil texture and the moisture characteristic associated with each plot. To do this, I performed hydrometer tests for particle size distributions and developed soil moisture retention curves using a Decagon WP4 Dewpoint PotentiaMeter *(Figure 1.)*.

Results showed that the soil moisture potential was well correlated on the alien-dominated sites when the three sites where plotted as one curve while the soil moisture potentials associated with the native-dominated sites had to be plotted separately to achieve reasonable R^2 values when power law curves were fit to the data. Interestingly, when all four moisture release curves were plotted on the same graph they were found to be in the same order as the varying degrees of seedling survival.

The WP4 was well suited to this project. I have used other techniques to develop moisture release curves that required a lot of training and experience to achieve sometimes marginal results. I was pleased with the WP4 performance because of its ease of use and range of measurement. Research, both published and unpublished, indicates that sagebrush is capable of living in environments as dry as -7 MPa. Measurement ranges from -0.02 MPa to -40 MPa were made to plot these curves which was more than adequate for this investigation..

Plant-available water and plant survival are logically connected. However, the factors that limit water availability across the landscape aren't always as straightforward. Your continuing efforts to develop reliable and easy to use tools, such as the WP4 PotentiaMeter, are making it possible to investigate some of the connections that can be made using ecological data from across a landscape. It is my hope that more successful and cost-effective mitigation projects will result from these efforts in the future. ■

Simplified measurements are appreciated.

Kansas State University
Evapotranspiration Laboratory

Department of Agronomy
2004 Throckmorton Hall
Manhattan, Kansas 66506-5501

" ... I want to say how much I appreciate the instruments made by you. I demonstrate them to my class. I appreciate the fact that you try and simplify measurements as much as possible. This is helpful for the many foreign students in my class, who will go back to countries where high-technology support services are not available Also, I appreciate the fact that you make instruments that are commercially available, with instruction manuals, so people like me (and Mr. Gang Mo) , who do not have the time or skill to make instruments, can make measurements.

Thank you for the excellent equipment that you provide. ..."

Sincerely yours,

M.B. Kirkham
Professor

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