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Priming Seed for Improved Vigor

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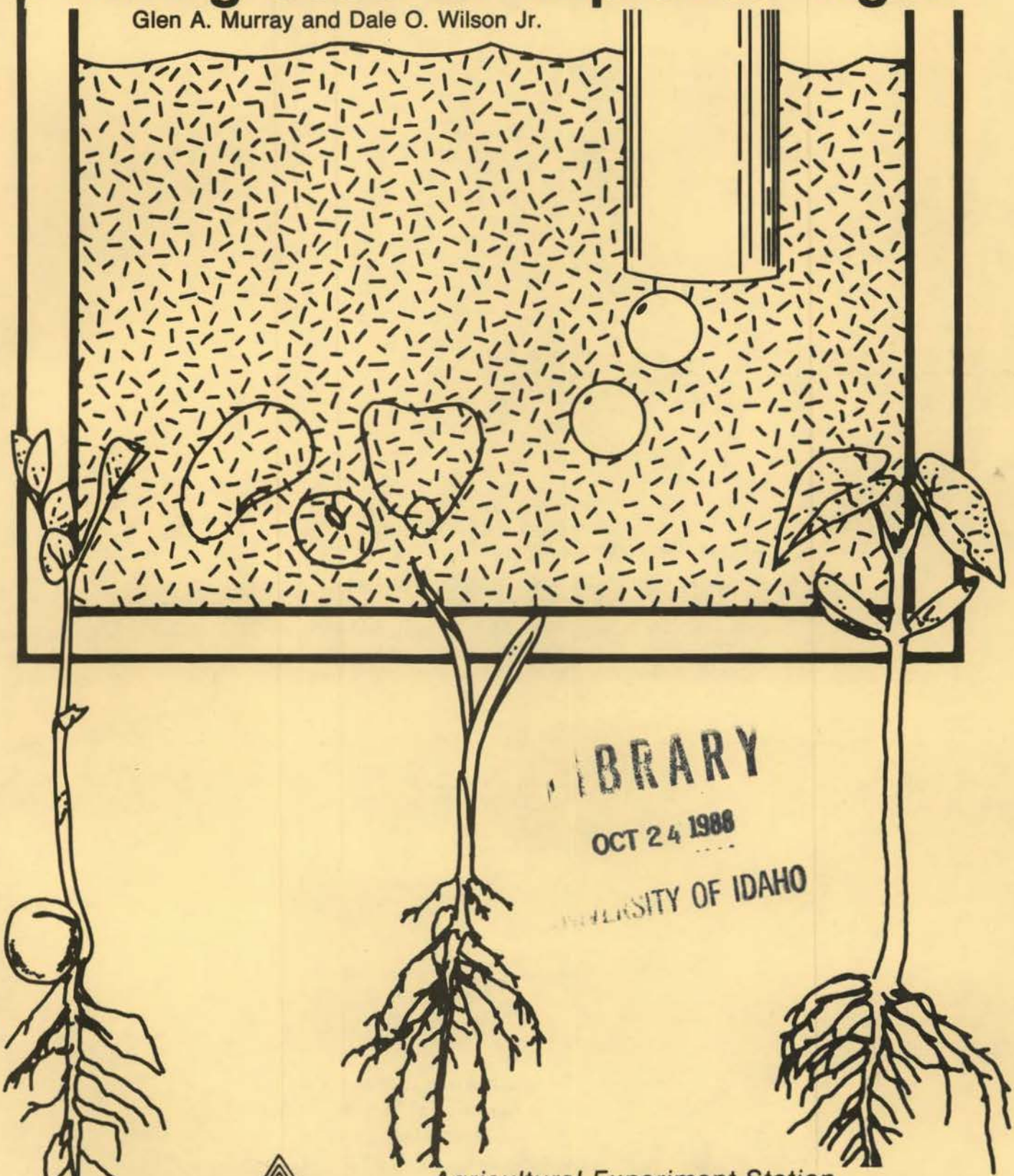

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Priming Seed for Improved Vigor

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Internal seed factors and environmental conditions often cause slow, irregular seedling growth and poor stands. Seeds that are old, immature or mechanically damaged are particularly susceptible to the stresses that occur when they are planted under adverse conditions in the field. Very dry seeds, especially those of large-seeded legumes, may be severely damaged by rapid water imbibition in moist soil. The injury is greatly aggravated by low temperature. Adding water to the seed in a controlled manner before planting (seed priming) can reduce these stresses, give seed germination a head start and minimize certain effects of seed age. Rapid seedling establishment also reduces effects of diseases, insects and soil stresses caused by drying and crusting.

Various experimental techniques, including some commercial technology, are available for controlled addition of water to seeds. The purpose of this publication is to describe the methods and rationale for these techniques and give experimental results from seed priming efforts.

Pregermination, Priming and Moisturizing

Although methods for adding moisture to seeds, ways of handling the resulting product and terminology describing the process are highly diverse, the techniques generally fall into three classes: pregermination, priming and moisturizing. In the pregermination process, the seed is placed in water and brought up to or close to the moisture level needed for germination (30 to 50 percent) and then planted in the imbibed state. Priming is a similar process except that water uptake is usually regulated by an osmoticum such as polyethylene glycol (PEG) or salt, and the seed is usually redried before planting. Moisturizing denotes the addition of smaller amounts of water to very dry seed (final seed moisture 10 to 25 percent) to improve its resistance to mechanical damage and imbibitional injury. The product remains sufficiently dry to permit ordinary handling. The pregermination and priming processes are described in this publication; moisturizing will be discussed in a future publication.

Pregermination

The rationale behind pregermination is to give the seed a head start by completing the first phase of the germination process (imbibition) before planting. The major disadvantage of this method is difficulty in storing and planting the very moist seeds which may possess protruding radicles. Also, some seeds are susceptible to damage by rapid uptake of water.

Imbibed seeds can be successfully redried if the germination process has not progressed too far. Much of the beneficial effect of imbibition is conserved in the dried product, and the seeds can be safely stored after treatment.

To prevent germination from progressing beyond the point at which the seed can be safely redried, some control of the germination process is needed. Germination control is accomplished by controlling the time seed is exposed to water, by keeping water temperature below optimum for germination or by limiting water availability, used separately or in combinations. Seed priming employs these techniques.

The Seed Priming Concept

Controlling the amount of water imbibed by the seed and the rate of water uptake is the most reliable approach to seed priming. This can be accomplished by exposing the seeds to moist air, placing them on or in moistened solid media or by simply adding a measured quantity of water with an osmotic agent. The concentration of the osmotic agent regulates the amount and rate of water uptake by the seed. Salts, polyethylene glycol and mannitol are common osmotic agents used for priming.

Some crops are sensitive to salt during seed germination. For these crops, polyethylene glycol (PEG) is a better osmoticum than salt for seed priming (Fig. 1). Polyethylene glycol is

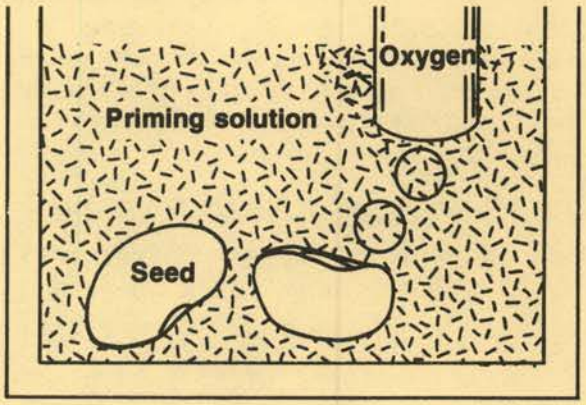

Fig. 1. General seed priming technique. Seed primed and fully immersed in polyethylene glycol requires additional oxygen.

non-toxic to seed because the large molecular size of PEG prevents its entry into the cells. However, as the concentration of PEG increases, oxygen supply to the seed decreases. Therefore, air must be bubbled through the priming medium when PEG is used. As seeds slowly absorb water, the metabolic reactions leading to germination begin. Seeds continue to absorb water until they have reached equilibrium with the osmotic solution.

The priming solution is often kept at temperatures below optimum for germination so that germination proceeds slowly. Priming continues until seeds are ready to sprout, but no sign of sprouting is visible.

Why Does Priming Work?

Priming allows many metabolic steps necessary for germination to take place before planting. The seed is ready to germinate, but cell elongation is inhibited by lack of water. When the seed is planted in moist soil, emergence occurs very rapidly and uniformly, giving the primed seed a head start over untreated seed.

Recent evidence suggests that the useful effects of seed priming may be more complex than simply a head start on germination. The physiological processes that occur as seeds age during storage seem to be related to changes that take place when the seed is hydrated and redried. Researchers have found that brief (less than 1 day) hydration-dehydration treatments increase field emergence when applied to seed lots old enough to show some decline in field emergence ability (Goldsworthy et al. 1982; Kundu and Basu 1981). These workers could show no benefit of such treatments to fresh, high quality lots. Hydration-dehydration treatments applied to old seed lots also seem to delay additional damage from further aging. Storage deterioration of seeds is a cumulative process, and hydration-dehydration treatment may somehow reset the clock. Perhaps high-value seed lots can be stored far longer than normally possible by periodic wetting-drying cycles. Little is known about the physiology of the imbibing seed.

Other Benefits of Seed Priming

Besides the direct enhancement response of seeds to hydration, other enhancement treatments may be conveniently applied during the course of seed priming. Certain vegetable seeds have a problem with dormancy induced by high temperatures after planting. Cool temperatures and light during priming help overcome this problem (Cantliffe et al. 1984; Valdes et al. 1985). Growth regulators applied to seeds during priming have significantly improved seed quality (Palevitch and Thomas 1978; Brocklehurst et al. 1982-83). Fungicides also may be added as part of the priming treatment to control certain diseases.

Experimental Priming Systems

Various crops respond differently to seed priming, so no universal recipe can be applied to all crops. Even within a single species, different investigators have arrived at different conditions, usually by trial and error. Table 1 lists crops that have been investigated and briefly describes the priming method and the effect on seed quality (Bradford 1986).

Priming seeds requires a vessel to contain the priming solution and seeds. An air stone or other diffusion device is placed at the bottom of the vessel and air is pumped through it to maintain sufficient oxygen for metabolic processes and to stir the soaking seeds. Fungicides are often added to the priming solution to prevent infection of the seed during the priming process and for disease control after planting. After treatment, the seeds are typically rinsed with water and air-dried. Rate and temperature of drying may be important for some crops.

Primed sugarbeet and onion seed have shown enhanced seedling emergence in Idaho field trials, particularly when soils are cold and wet at planting time. Seedling performance was not always improved by priming. Some onion varieties have shown no response. Final plant stands of both onions and sugarbeets were not increased under conditions favorable for emergence. Results of these trials will be discussed in future publications.

Priming may be an effective way to improve seedling performance of several Idaho crops, especially under unfavorable conditions. It may also reduce damage to seed during storage and handling. Further information concerning seed priming may be obtained from the listed references or by contacting the authors.

Table 1. Crop responses to experimental seed priming conditions.

Crop	Solution*	Temp. (C)	Duration (days)	Results
Barley (*Hordeum vulgare* L.)	PEG (−0.5 to −1.5 MPa)	10	1-8	Accelerated germination at 10C: improved uniformity
	Na_2HPO_4 (1 mM)	—	0.25	Improved yield
	$Al(NO_3)_2$ (0.62 mM)		0.83	
	$Co(NO_3)_2$ (0.69 mM)		0.83	
Beet (*Beta vulgaris* L.)	KNO_3 (0.3 M) + K_3PO_4 (0.14 M) NaCl (0.45 M) $MgSO_4$ (0.83 M)	10-22	4-21	Accelerated germination at −0.5 MPa; optimum conditions 0.24 M NaCl, 15C, 6 days
	NaCl (0.34 M)	15	6	Improved emergence at low soil moisture; increased seedling dry weight at low temperature
	PEG (−1.2 MPa)	15	7	Improved germination; improved field and greenhouse emergence; increased yield
	$MgSO_4$ (−1.18 MPa)			
Broccoli (*Brassica oleracea* L. var. *italica*)	PEG (156 to 282 g•kg^{-1})	10, 20	1-21	Reduced germination
Brussels sprouts (*Brassica oleraca* L. var. *gemmifera*)	PEG (250 g•kg^{-1})	15	7	Accelerated emergence, increased plant fresh weight
Cabbage (*Brassica oleracea* L. var. *capitata*)	PEG (250 g•kg^{-1})	15	—	Accelerated emergence, increased plant fresh weight
	PEG (305 g•kg^{-1})	15	14	Accelerated emergence in heat-damaged seed
Cantaloupe (*Cucumis melo* L.)	KNO_3 (0.3 M)	25	6	Improved germination and field emergence at low temperature
Carrot (*Daucus carota* L.)	PEG (273 g•kg^{-1})	15	14	Accelerated germination at 15C
	PEG (273 g•kg^{-1})	15	14	Accelerated field emergence; increased plant fresh weight
	PEG (342 g•kg^{-1})	15	14	Improved germination and emergence (PEG and KH_2PO_4); glycerol ineffective
	KH_2PO_4 (0.5 M)			
	Glycerol			
	PEG (156 to 282 g•kg^{-1})	10, 20	1-21	Reduced germination
	PEG (250 g•kg^{-1})	15	6	Improved germination and emergence at low temperature; improved stand uniformity and yield
Celery (*Apium graveolens* L.)	PEG (273 g•kg^{-1})	15	14	Accelerated germination at 15C
	PEG (273 g•kg^{-1})	15	14	Accelerated greenhouse emergence; increased plant fresh weight
	PEG (273 g•kg^{-1}) + GA_{4+7} + ethephon	15	14	Improved germination at high temperature
	PEG (200 to 250 g•kg^{-1})	15	7-21	Improved germination at high temperature
	PEG (200 g•kg^{-1}) + 0.2% thiram	20	7-29	Accelerated germination at 15C
	PEG (−1.17 MPa)	—	7, 14	Improved germination above 20C
	PEG (279.5 g•kg^{-1})	18	14	Improved greenhouse emergence at 15C; improved plant development before final harvest
	PEG (−1.5 MPa)	15	14	Improved germination at high temperature
	PEG (342 g•kg^{-1})	15	14	PEG and KH_2PO_4 improved germination and emergence; glycerol less effective
	KH_2PO_4 (0.5 M)			
	Glycerol (112 g•kg^{-1})			
Corn (*Zea mays* L.)	PEG (−0.5 to −1.5 MPa)	10	1-8	Accelerated germination and improved uniformity at low temperature
	PEG (250 g•kg^{-1}) + 0.2% thiram	15	8	Improved germination at 10C; increased seedling growth rate

Table 1. (Cont'd)

Crop	Solution*	Temp. (C)	Duration (days)	Results
Lettuce (*Lactuca sativa* L.)	K_3PO_4 (0.05 M) PEG (−0.51 MPa)	15	0.38	Improved germination at 30C; improved field emergence
	K_3PO_4 (0.05 M)	>5-25	>0.25-0.5	Improved germination at 35C
	PEG (250 g•kg^{-1})	15	14	Accelerated germination at low temperature
	PEG (250 g•kg^{-1})	15	1-14	Accelerated germination
	PEG (345 g•kg^{-1})	18-20	1	Improved emergence at high temperature of pelleted seed
Leek (*Allium porrum* L.)	PEG (342 g•kg^{-1}) KH_2PO_4 (0.5 M) Glycerol (112 g•kg^{-1})	15	14	All treatments reduced mean emergence time; KH_2PO_4 lowered emergence percentage
	PEG (342 g•kg^{-1})	15	7-21	Improved rate and uniformity of germination and emergence
Onion (*Allium cepa* L.)	PEG (342 g•kg^{-1})	15	14	Accelerated germination
	PEG (342 g•kg^{-1})	15	14	Accelerated emergence; increased plant fresh weight
	PEG (342 g•kg^{-1}) KH_2PO_4 (0.5 M) Glycerol (112 g•kg^{-1})	15	14	Reduced mean time for germination and emergence
	PEG (250 g•kg^{-1})	9-21	4-12	Accelerated germination
	PEG (−1.1 to −1.4 MPa)	10	21	Accelerated germination and seedling growth
Parsley (*Petroselinum hortense* Hoffm.)	PEG (296 g•kg^{-1})	15	21	Accelerated germination at 15C; increased yield
	PEG (−1.25 MPa)	15.5	10	
Parsnip (*Pastinaca sativa* L.)	PEG (342 g•kg^{-1})	15	18	Accelerated germination and field emergence
Pea (*Pisum sativum* L.)	PEG (250 to 500 g•kg^{-1})	15	4, 8	Accelerated germination; increased root and shoot growth rates
Pepper (*Capisicum annum* L.)	PEG (240 g•kg^{-1})	15	5	No effect
	KNO_3 (0.1 to 0.3 M)	20-22	6	Improved germination and emergence; increased plant fresh weight
	PEG (−0.4 to −1.2 MPa)	20-22	5	
	KH_2PO_4 (0.11 M + $(NH_2)_2HPO_4$ (0.11 M)	27-29	3	Accelerated germination and greenhouse emergence; improved yield in one cultivar
(*C. frutescens* L.)	KNO_3 (0.3 M)	20-22	6	Accelerated germination at 15C and above
	PEG (−0.4 MPa)		5	
Sorghum [*Sorghum bicolor* (L.) *Moench*]	PEG (−0.5 to −1.5 MPa)	10	1-8	Accelerated germination; improved uniformity at low temperature
Soybean [*Glycine max* (L.) Merrill]	PEG (−0.5 to −1.5 MPa)	10	1-8	Accelerated germination; improved uniformity at low temperature
	PEG (250 to 350 g•kg^{-1}) + 0.2% thiram	15	4-10	Accelerated emergence; increased seedling growth rate
	PEG (250 g•kg^{-1})	15	11	Accelerated emergence
	PEG (250 g•kg^{-1}) + 0.2% thiram + 1200 U penicillin G	10	4	Accelerated germination at 10C
	PEG (300 g•kg^{-1})	25	.08-.33	Improved germination in aged seed
Spinach (*Spinacea oleracea* L.)	PEG (298 g•kg^{-1})	10	14	Improved germination at high temperature
	PEG (−1.03 to −1.18 MPa)	—	7, 14	Improved germiation at high temperature
Tomato (*Lycopersicon esculentum* Mill.)	PEG (−0.25 to −1.18 MPa)	25	5-35	Accelerated germination
	Mannitol (0.1 to 1.6 M)	25	0.25-7	Accelerated germination and overcame inhibition by far-red light
	KH_2PO_4 (0.11 M) + $(NH_4)_2HPO_4$ (0.11 M)	27-29	3	No effect on emergence
	PEG (−0.75 MPa) + fusicoccin 10μM)	20	7	Accelerated germination at low temperature

Table 1 (Cont'd)

Crop	Solution*	Temp. (C)	Duration (days)	Results
	PEG (−0.75 MPa)	20	7	
	KNO_3 (0.15 M) + K_3PO_4 (0.07 M)	24	5	
	PEG (−0.5 MPa	15	7	Accelerated emergence; earlier ripening
Watermelon [*Citrullus lanatus* (Thunb.)] Matsum. and Nakai	KNO_3 (0.2 to 0.3 M) NH_4NO_3 (0.2 M) $NaNO_3$ (0.2 M) $Ca(NO_3)_2$ (0.1M) KC1 (0.1 M)	30-35	6	Improved germination and greenhouse emergence at low temperatures
Wheat (*Triticum aestivum* L.)	PEG (0.5 to −1.5 MPa)	10	1-8	Improved germination

*The concentrations for salt solutions have been converted to molar units when possible. PEG solutions are all PEG 6000 (now renamed PEG 8000), and are reported as either grams per kilograms of water or MPa, depending on the original citation. No attempt has been made to convert these to uniform units, as different calculations or measurements may have been used by different authors. The conversion of grams per kilograms of PEG 6000 to MPa is highly temperature-dependent. Equations for calculating for PEG solutions at any temperature can be found in Michel (1983) and Bradford (1986).

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