cucumber vines and fruit with bare soil to promote growth and limit mechanical and disease damage to fruit. Black plastic mulch is a cultural tool used, in part, to keep plants from contact with the soil. Even when black plastic mulch is used, trellising improved yields over ground-cultured plants. This improvement can be translated into potentially greater profits for the producer.

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A Comparison of Priming Agents for Tomato and Asparagus Seeds

J.J. Frett¹, W.G. Pill², and D.C. Morneau³

Delaware Agricultural Experiment Station, Department of Plant and Soil Sciences, College of Agricultural Sciences, University of Delaware, Newark, DE 19717-1303

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Abstract. Tomato (*Lycopersicon esculentum* Mill.) and asparagus (*Asparagus officinalis* L.) seeds were primed for 1 week in -0.8 MPa (20C, dark) polyethylene glycol 8000 (PEG), synthetic seawater (INO), or combinations of Ca^{+2} , K^{+} , or Na^{+} with Cl^{-} , NO_3^{-} , $\text{H}_2\text{PO}_4^{-}$, or SO_4^{-2} and then were placed in 0.5-fold Hoagland solution at 20C for germination. Priming did not affect percentage germination of tomato seeds; but asparagus germination increased from 85% in untreated seeds to 90% due to priming. All priming treatments reduced the time to 50% germination (G_{50}) of both species but reduced the time between 10% and 90% germination (G_{10-90}) of only tomato seeds. Salt solutions gave lower G_{50} values than PEG for tomato seeds but did not provide this advantage for asparagus seeds. The G_{50} and G_{10-90} of tomato seeds were lower after priming with nitrate salts than with other salts, but the reductions were greatest with sodium nitrate. The G_{50} of asparagus seeds was lowered with nitrate salts, but the G_{10-90} was unaffected.

Seed priming involves exposing quiescent seeds to a solution or matricum of low water potential that permits partial seed hydration without seed germination (Bradford, 1986). This seed treatment can improve seed germination and seedling emergence, particularly under adverse seedbed conditions, such as low temperature (Pill and Finch-Savage, 1988), reduced water availability (Frett and

Pill, 1989), or salinity (Wiebe and Muhyadin, 1987).

The optimal priming treatment for a seed lot is determined by trial and error (Bradford, 1986). Variable factors include the duration of seed exposure to the priming agent (Evans and Pill, 1989; Frett and Pill, 1989; Pill and Finch-Savage, 1988), the temperature and water potential of the priming agent (Evans and Pill, 1989; Frett and Pill, 1989; Haigh and Barlow, 1987), and the nature of the priming agent (Bradford, 1986; Haigh and Barlow, 1987).

A commonly used seed priming agent is polyethylene glycol (PEG) of ≈ 8000 molecular weight. Molecules of this size are colloidial, and so the reduced water potential is derived matrally. While PEG is inert and nonphytotoxic, it is costly and sufficiently viscous to hinder aeration (Mexal et al., 1975). Inorganic salts such as KNO_3 , KH_2PO_4 , and K_3PO_4 also are used as priming agents (Haigh and Barlow, 1987). Dissociated ions from such salts can penetrate seed tissues, whereas PEG molecules do not.

Variable uptake of different ions from priming salts would not only influence the amount of water absorbed by the seeds along the osmotic gradient but may also exert disruptive specific ion effects on enzymes and membranes. We know of no published reports on the use of seawater as a priming osmoticum. Seawater would be an inexpensive alternative to technical or reagent grade salts or PEG, at least in some locations.

Here we report on the germination responses of tomato (exalbuminous, moderately salt sensitive) and asparagus (albuminous, salt tolerant) seeds following priming in various inorganic salts, synthetic seawater or PEG.

Seeds of 'Ace 55' tomato and 'Mary Washington' asparagus were primed for 1 week in darkness in -0.8 MPa solutions at 20C. Factorial combinations of Ca^{+2} , Na^{+} , or K^{+} with NO_3^{-} , Cl^{-} , SO_4^{-2} , or $\text{H}_2\text{PO}_4^{-}$ were used except that CaSO_4 and $\text{Ca}(\text{H}_2\text{PO}_4)_2$ were excluded due to low solubility (2.1 g and 18.0 g-liter⁻¹ H_2O , respectively). Other priming agents were PEG 8000 and synthetic seawater (INO; Instant Ocean, Aquarium Systems, Mentor, Ohio). The concentrations of all priming agents (Table 1) were determined from standard curves relating concentrations to osmotic potentials as developed with a Wescor Model 5500XR Vapor Pressure Osmometer (Wescor, Logan, Utah). Untreated seeds were included as controls.

The seeds were primed in $125 \times 80 \times 20$ -mm transparent polystyrene boxes containing two layers of germination paper (Seed Germination Blotters, no. 385, Seedburo Co., Chicago) that were moistened with 15 ml of priming solution. Each treatment consisted of five replicated boxes each containing 50 seeds. Replications were arranged in completely randomized blocks.

Following priming, the seeds were rinsed in deionized water and transferred into boxes containing germination blotters moistened with 15 ml of 0.5-fold Hoagland solution (Hoagland and Arnon, 1950). Germinated seeds (radicles visible) were counted daily and removed from the boxes. From these data, final germination percentage (FGP), days to 50% of FGP (G_{50}) and days between 10% and 90% of FGP (G_{10-90}) were calculated.

Priming treatments had no effect on FGP of tomato seeds, with all treatments aver-

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¹Assistant Professor.

²Associate Professor.

³Undergraduate Student.

Table 1. Days to 50% germination (G_{50}) and days between 10% and 90% germination (G_{10-90}) of 'Ace 55' tomato seeds and 'Mary Washington' asparagus seeds in 0.5-fold Hoagland solution at 20°C in darkness as influenced by seed priming (all at -0.8 MPa, 20°C, 1 week, dark) treatments.

Treatment ^z	Concn (g·liter ⁻¹)	Tomato		Asparagus	
		G_{50} (days)	G_{10-90} (days)	G_{50} (days)	G_{10-90} (days)
Ca(NO ₃) ₂	31.5	0.6	1.2	2.3	5.2
CaCl ₂	19.0	0.8	1.4	2.4	5.4
Na ₂ SO ₄	20.4	1.0	1.6	2.9	6.1
NaNO ₃	15.7	0.5	0.8	1.9	5.3
NaH ₂ PO ₄	25.7	1.0	1.6	2.5	5.3
NaCl	10.6	1.1	1.7	3.0	6.1
K ₂ SO ₄	25.6	0.8	1.6	2.8	5.4
KNO ₃	19.3	0.6	1.3	2.1	4.9
KH ₂ PO ₄	25.8	0.7	1.6	2.8	5.5
KCl	13.4	0.9	1.6	2.7	5.9
INO	13.7	1.0	1.6	2.7	5.2
PEG	310.0	1.4	1.5	2.8	6.3
None		3.5	2.3	7.5	5.2

Orthogonal contrast significances

Treatments					
None vs. primed	***	***	***	NS	
PEG vs. salts	***	NS	NS	NS	
INO vs. other salts	*	NS	NS	NS	
Ca ²⁺ vs. (Na ⁺ and K ⁺) (C1)	NS	NS	NS	NS	
Na ⁺ vs. K ⁺ (C2)	*	NS	NS	NS	
NO ₃ ⁻ vs. (SO ₄ ²⁻ , H ₂ PO ₄ ⁻ and Cl ⁻) (A1)	***	***	***	NS	
SO ₄ ²⁻ vs. (H ₂ PO ₄ ⁻ and Cl ⁻) (A2)	NS	NS	NS	NS	
H ₂ PO ₄ ⁻ vs. Cl ⁻ (A3)	NS	NS	NS	NS	
C1 × (NO ₃ ⁻ vs. Cl ⁻)	NS	NS	NS	NS	
C2 × A1	***	***	***	NS	
C2 × A2	NS	NS	NS	NS	
C2 × A3	NS	NS	NS	NS	

^zINO = Instant Ocean (synthetic seawater); PEG = polyethylene glycol.

NS,*,***Orthogonal contrasts nonsignificant or significant at $P \leq 0.05$ or 0.001, respectively.

aging 92% germination; but priming increased asparagus FGP from 85% in untreated seeds to 90%. The lack of priming effect on FGP of tomato seeds has been reported (Alvarado and Bradford, 1988; Haigh and Barlow, 1987). In contrast to the present results, Evans and Pill (1989) found no effect of priming on FGP of asparagus seeds.

Priming treatments decreased the G_{50} of tomato and asparagus seeds (Table 1). Salt solutions as a group, including INO, gave lower G_{50} values for tomato seeds than PEG, but the G_{50} values for asparagus seeds were similar for all priming treatments. Haigh and Barlow (1987) found that inorganic salts were superior to PEG for improving germination of tomato and carrot seeds, but the opposite was true for onion and sorghum seeds. Alvarado and Bradford (1988) observed that the more rapid germination following KNO₃-priming than PEG-priming was associated with a higher seed moisture content and presumably a more advanced stage of development.

During the 1-week soak in salt solutions, certain cations or anions could have been absorbed preferentially that could have exerted both specific ion and osmotic effects. Similar G_{50} and G_{10-90} values following priming in INO or NaCl (Table 1) would be expected since the salt in seawater is ≈85% w/w NaCl. Although the G_{50} values of tomato seeds were statistically lower with K-salts than with Na-salts (Table 1), the differences were too small to be of practical significance.

Of all the salt solutions, the effect of NO₃-salts in reducing the G_{50} of tomato and asparagus seeds and in reducing the G_{10-90} of tomato seeds was most pronounced (Table 1). For tomato seeds, NaNO₃ gave the lowest G_{50} and G_{10-90} values. Haigh and Barlow (1987) found that tomato seeds primed in solutions that contained KNO₃ germinated more rapidly and synchronously than those primed in solutions without KNO₃. The NO₃-salts may be absorbed preferentially to lower the internal osmotic potential and thereby

encourage water influx, an effect that would explain the alleviation of "underpriming" by inclusion of KNO₃ in the priming solution (Haigh and Barlow, 1987). Nutritional effects of nitrate uptake during priming in providing additional substrate for amino acid and protein synthesis also are possible.

Our results show that the major effect of priming tomato and asparagus seeds was a decrease in the time to 50% germination. While salt solutions were more effective than PEG in reducing the G_{50} of tomato seeds, salt solutions provided no such benefit for asparagus seeds. Of the salt solutions, NO₃-salts were most effective in reducing the G_{50} of tomato and asparagus seeds and reducing the G_{10-90} of tomato seeds. Synthetic seawater, at about one-third full strength, was as effective as PEG as a priming agent for asparagus seeds and was superior to PEG as a priming agent for tomato seeds.

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