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Priming Leek Seed for Improved Germination and Emergence at High Temperature

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Abstract. **'Verina' leek *(Allium porrum* L.) seed germination is normally reduced at temperatures > 25C. Leek seeds were primed in aerated solutions (- 1.5 MPa, 10 days at 15C) of d-mannitol (mannitol), polyethylene glycol-8000 (PEG_a), KNO_3, and a nonaerated solution of PEG-8000 (PEG_{na}). At high temperatures mannitol, PEG_a, and PEG_{na} significantly enhanced germination percentage relative to KNO_3, or the control. At constant 30C, the mannitol, PEG_a, and PEG_{na} treatments increased final germination almost 10 times and the coefficient of velocity (COV) was improved compared to KNO_3, and the control. 10 growth chambers with alternating day/night temperatures (38 to 28C or 32 to 22C, 10 to 14 hours, respectively), primed seeds had significantly higher emergence and a larger COV than the control. In a greenhouse study under good conditions for germination, total emergence of primed and nonprimed seeds was similar; however, mannitol, PEG_a, and PEG_{na} led to a significantly higher COV than the control or KNO_3, treatments. These controlled-environment results demonstrate that priming leek seeds via mannitol, PEG_a, and PEG_{na} may promote early emergence at high temperature and improve stand uniformity for container transplant production.**

The period between planting seeds and the emergence of the seedlings is critical for stand establishment and the eventual yield of most crops. In Florida, leek is generally established by transplanting in the fall. Because plants for this production must be sown in July and August, containerized leek transplant production is susceptible to heat stress, resulting in poor and nonuniform seedlings. Seed priming has increased the uniformity and early emergence of many crops, especially under conditions of environmental stress (Bradford, 1986). Plant establishment becomes extremely difficult at high temperature (Cantliffe, 1989). Seed priming with K_3PO_4 has successfully increased the germination percentage and rate for lettuce *(Lactuca sativa* L.) seeds sown at high temperature (Guedes and Cantliffe, 1980). Under heat stress, the time required for the emergence of tomato *(Lycopersicum esculentum* Mill.) seedlings was reduced and higher uniformity was achieved by priming in K_3PO_4 + KNO_3 solution (Ode11 and Cantliffe, 1987). Pansy *(Viola tricolor* L.) seeds primed in aerated solutions of PEG 8000 had significantly higher germination at 35C than nonprimed seeds (Carpenter and Boucher, 1991).

Leek seed is characterized by low emergence percentage, which leads to poor stands (Brocklehurst et al., 1984). Seed primed in nonaerated PEG solutions has been reported as an effective presowing treatment in leek for reducing the mean time and increasing the uniformity of germination (Bray et al., 1989; Brocklehurst et al., 1984). However, the experiments reported were conducted at low temperature (15C). Our objective was to compare priming treatments to improve germination and emergence of leek under heat stress.

Seeds of 'Verina' leek (Northrup King, Gilroy, Calif.) were used in all experiments. Two hundred seeds (0.44 g) were soaked in 35 ml of osmotic solution (- 1.5 MPa) of D-mannitol, polyethylene glycol-8000 (PEG_a), or KNO_3 in 150-mm test tubes and aerated with an aquarium pump. The water potential of the solutions was measured in a Wescor vapor pressure osmometer (Wescor, Logan, Utah) at 25C. The priming treatments were for 10 days at 15C in dark. The nonaerated priming treatment (PEG_{na}) consisted of placing 200 seeds on filter paper (Whatman #3) moistened with 5 ml of PEG-8000 at - 1.5 MPa in a 9-mm petri dish. The container was sealed with parafilm (American National Can, Greenwich, Conn.) to prevent water evaporation. It has been reported that the filter paper lowers the original water potential when the ratio volume of solution, air dry weight of the filter paper, is <12 (Hardegree and Emmerich, 1990). In our experiment the ratio was 5; thus, we expected a more negative water potential (-0.02 MPa) than the original solution. The soak time and temperature for nonaerated priming were the same as described for the aerated treatments. After priming, the seeds were rinsed with tap water (1 min) and dried back to the original fresh weight (6.2%) at 15C and 30% relative humidity (RH). The seeds were stored before

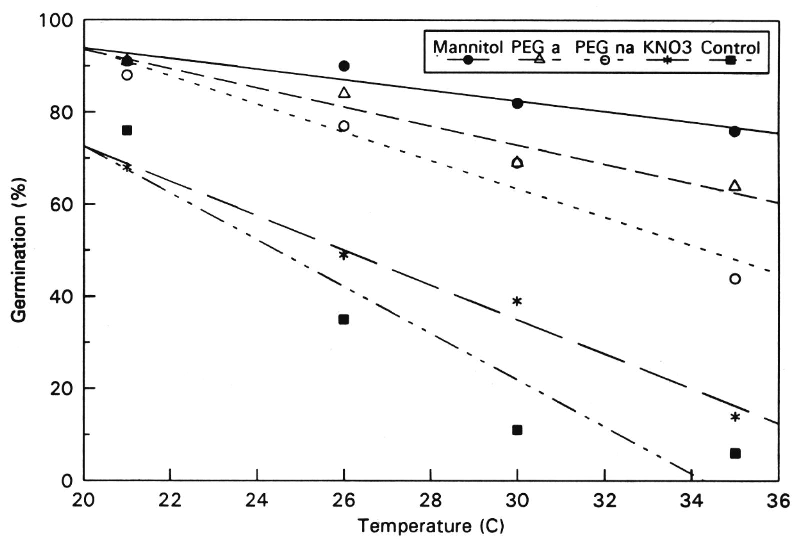

Fig. 1. Relationship between temperature (°C) and germination (%) of 'Verina' leek in response to priming treatments. The regression equations for the lines were: mannitol: y = 116.7 - 1.14x *(R^2 = 0.55)*; PEG_a: y = 136.9 - 2.13x *(R^2 = 0.72)*; PEG_{na}: y = 155.1 - 3.06x *(R^2 = 0.41)*; KNO_3: y = 147.4 - 3.7x *(R^2 = 0.62)*; control: y = 174.1 - 5.08x *(R^2 = 0.78)*. Treatments: mannitol: aerated solution; PEG_a: aerated solution PEG-8000; PEG-8000; PEG-8600 on filter paper; $KN0_3$: aerated solutions $KN0_3$. All: - 1.5 MPa, treated 10 days at 15C. Control: nonprimed seeds.

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Table 1. Final germination percentage (7 days) of 'Verina' leek at various temperatures on a thermogradient table as influenced by priming treatment.

Treatment[z]	Temp (°C) 21	26	30	35	LSD (0.05)
			Germination (%)		
Mannitol	91	90	82	76	9
PEG_a	91	84	69	64	10
PEG_{na}	88	77	69	44	32
KNO_3	68	49	39	14	20
Control	76	35	11	6	20
LSD (0.05)	NS	18	26	22	

[z]Mannitol: aerated solution; PEG_a,: aerated solution of PEG-8000, PEG_{na}: PEG-8000 on filter paper; KNO_3: aerated solutions KNO_3. All: - 1.5 MPa, treated 10 days at 15C. Control: nonprimed seeds.

Table 2. Final emergence percentage and coefficient of velocity (COV) of primed and nonprimed seeds of 'Verina' leek at constant and alternating temperatures.

	Day/night temp (°C)							
	30[y]		38 to 28[x]		32 to 22[x]		34 to 24[w]	
Treatment[z]	Germination (%)	COV	Emergence (%)	COV	Emergence (%)	COV	Emergence (%)	COV
Mannitol	55	25.3	43	13.0	55	21.7	71	21.3
PEG_a	48	23.9	35	12.2	49	19.7	71	21.3
PEG_{na}	49	26.8	38	11.5	41	20.3	67	20.9
KNO_3	6	20.5	23	10.8	40	18.8	51	18.3
Control	6	18.9	15	9.3	16	10.6	63	15.8
LSD (0.05)	13	4.2	9	1.2	19	3.6	NS	2.3

[z]Mannitol: aerated solution; PEG_a: aerated solution PEG-8000; PEG_{na}.: PEG-8000 on filter paper; KNO_3: aerated solutions KNO_3. All: - 1.5 MPa, treated 10 days at 15C. Control: nonprimed seeds.
[y]Incubator.
[x]Growth chamber.
[w]Greenhouse.

and after treatment at 10C and 45% RI-I.

Germination tests were conducted on a thermogradient table (21 to 35C) in darkness. Twenty-five seeds were placed on a single steel blue germination blotter (Anchor Paper Co., St. Paul, Minn.) and covered with a 9-mm glass petri dish. Water was added as needed and germination was recorded daily. Germination was defined as visible radicle protrusion through the seedcoat and final germination was calculated after 7 days. A germination test was also carried out in an incubator at a constant 30C and 35% RH. The seeds (25) were placed on a single steel blue germination blotter in a 9-mm glass petri dish, moistened with 5 ml of distilled water, and kept in darkness. Final germination was calculated after 7 days.

Primed seeds were also placed in a growth chamber at alternating day/night temperatures (38 to 28C or 32 to 22C, 50% RH, 10 to 14 h, respectively). Fifty seeds for each replication were sown in Speedling polystyrene trays (150 inverted pyramid cell) filled with Metro Mix 300 (Grace Sierra, Calif.). The trays were irrigated as needed with tap water and seedling emergence was recorded daily. The same experiment was conducted in a greenhouse at 34 to 25C alternating day/night average temperatures (14/10 h), respectively. The final germination and coefficient of velocity (COV) (Scott et al., 1984) in growth chamber and greenhouse experiments were calculated 10 days after sowing.

All the treatments were arranged in a complete randomized-block design with four replications. The thermogradient table experiment was conducted four times. Percentage data were arcsin transformed before analysis.

A significant negative relationship between germination percentage and temperature was found on the thermogradient table (Fig. 1). For all treatments, leek seed germination decreased as temperature increased. The slopes of germination for nonprimed seeds and for the KNO_3 treatment declined as more temperature increased than those for seeds primed with mannitol, PEG_a, or PEG_{na}, as osmotica. Germination of nonprimed seed was reduced >50% when the temperature increased from 21 to 26C (Table 1). Germination at 21C did not differ significantly for the priming treatments and control. As temperature increased, seed primed with mannitol, PEG_a, and PEG_{na} had significantly higher germination percentages than the nonprimed or KNO_3-primed seeds (Table 1). At 35C, total germination of seeds primed in mannitol was significantly higher than that of seed primed in PEG_{na}, $KN0_3$, or the control.

At constant 30C in an incubator, total and rate (COV) of seedling emergence were significantly higher for seeds primed in mannitol, PEG_a, or PEG_{na} than for those of the control or KNO_3 treatment (Table 2). At alternating high day/night temperatures (38 to 28C) similar responses were observed. At lower alternating temperatures (32 to 22C), significant differences were found in total seedling emergence and rate of emergence only between the priming treatments and control. Total emergence in the greenhouse was higher for all treatments than in the growth chamber. In the greenhouse, total emergence did not differ significantly among treated and nontreated seeds. However, seeds primed via mannitol, PEG_a, or PEG_{na} germinated significantly faster (higher COV) than seeds exposed to KNO_3 or nontreated seeds (Table 2).

Our results showed that germination of 'Verina' leek seed is severely affected by heat stress. Ellis and Butcher (1987) reported that priming did not influence the ceiling temperature of germination in onion *(Allium cepa* L.). We conclude that priming reduces the negative effects of high temperature on leek seed germination. Similar results have been reported in lettuce (Cantliffe, 1981; Guedes and Cantliffe, 1980), tomatoes (Ode11 and Cantliffe, 1987), and pansy (Carpenter and Boucher, 1991). Priming leek seed in aerated solutions of D-mannitol, PEG_a, or PEG_{na} at - 1.5 MPa for 10 days at 15C appeared to be effective for increasing total germination, seedling emergence, and velocity of emergence at high temperature. The poor performance of the KNO_3 treatment could be associated with damage to the germinating seed by the extended time (10 days) of contact between the salt and the embryo (Cantliffe, 1989). As previously reported in lettuce (Cantliffe, 1981) and dusty miller *(Senecio cineraria* DC.) (Carpenter, 1990), there were no statistical differences in performance of seeds primed in aerated and nonaerated solutions of PEG-8000. However, the seeds primed in aerated solutions showed less reduction in total germination at unfavorable temperatures. Also, larger quantities of seeds can be primed in aerated solution than with moist surface methods (Akers and Holley, 1986). The D-mannitol was an appropriate substitute for PEG-8000 as an osmoticum. The seeds primed in mannitol had the most rapid and uniform emergence in the thermogradient table, growth chamber, and greenhouse experiments. Priming via D-mannitol or PEG-8000 offers the possibility of improved leek containerized seedling production in Florida and other warm climates by increasing final germination and seedling uniformity. Additional experiments might be necessary to determine the treatment response with other seed lots or leek cultivars and the effect storage time has on the treatments.

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