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Osmotic Seed Priming of *Rudbeckia fulgida* Improves Germination and Expands Germination Range

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Abstract. **Low-vigor seeds of black-eyed Susan (*Rudbeckia fulgida* Ait.) primed in aerated –1.3 MPa KNO_3 for 7 days at 30C in darkness had double the total germination percentage at 30C and one-half the mean time of germination as nonprimed seeds. Priming the seeds in polyethylene glycol rather than KNO_3 generally resulted in lower total germination percentage and longer mean time of germination. Osmotic priming increased total germination percentage and germination rate of seeds germinated at 21.9 to 32.2C, but the priming benefit on total germination percentage was greater at ≤27.6C. Total germination percentage of primed and nonprimed seeds was highest at 28.8 to 32.2C.**

Rudbeckia fulgida, also known as black-eyed Susan, gloriosa daisy, and orange coneflower, is a herbaceous perennial popular in urban landscapes. It possesses heat tolerance, powdery mildew resistance, desirable ornamental qualities, and a long bloom season. Current germination recommendations for *Rudbeckia* are varied. Suggested germination regimes include 21 to 24C for 14 to 21 days (George J. Ball, 1989; G.W. Park Seed Co., 1989–90; Tayama, 1989), although official germination requirements for *R. fulgida* have not been established (Association of Official Seed Analysts, 1990). Difficulty in germination and variable germination rates can cost perennial plant producers time, money, and crop loss.

Seed priming reduces the germination time for many vegetable and herbaceous perennial crops (Brocklehurst and Dearman, 1984; Finnerty et al., 1992). Osmotic seed priming, alias osmoconditioning, is a process of controlled water imbibition by the seed through the use of osmotic solutions containing polyethylene glycol (PEG) (Heydecker et al., 1975) or inorganic salts (Heydecker and Coolbear, 1977). The seeds are "primed" to initiate metabolic and physiological processes without radicle emergence (Heydecker et al., 1975). Finnerty et al. (1992) found that priming enhanced germination percentage of the herbaceous perennials *Aquilegia caerulea* L. and *A.canadensis* L. As the priming duration increased for *A. caerulea*, so did the final percent germination.

The objectives of this study were to determine 1) the germination of *R. fulgida* seeds primed at various osmotic potentials of PEG 8000 or potassium nitrate at the defined optimum germination temperature (Fay et al., 1993b) and 2) the germination rate and total percent germination of osmotically primed *R. fulgida* seeds over a temperature gradient using a selected priming regime.

Materials and Methods

Osmoticum and osmotic potential. After determining the optimum germination temperature for *R. fulgida* (Fay et al., 1993b), preliminary studies were conducted to determine optimum osmotic seed priming conditions in aerated solutions. As Akers and Holley (1986) indicated, germination tests should be performed before priming to determine the osmotic agent, potential temperature of the osmoticum, and priming duration. Priming duration is defined (Akers and Holley, 1986) as the time necessary to reach a germination percentage plateau in aerated water. To determine the optimum priming duration, four replications of 100 seeds each from a low-vigor seedlot (Fay et al., 1993a) were hydrated in 100 ml of aerated distilled water at 30 ± 1C. Germination plateaued at 51% after 7 days. Thus, the duration of seed priming was established as 7 days (Akers and Holley, 1986).

Three replications of 50 seeds each were primed at 30 ± 1C for 7 days in solutions of potassium nitrate (KNO_3) or PEG 8000 at five osmotic potentials; for KNO_3, they were –0.6, –0.8, –1.0, –1.3, or –1.5 MPa prepared, respectively, by adding 9.5, 16.0, 22.0, 30.5, or 35.0 g KNO_3/liter of double-distilled water. Osmotic potentials for PEG 8000 were –0.5, –0.7, –1.0, –1.3, or –1.6 MPa prepared, respectively, by adding 180, 250, 300, 350, or 400 g PEG 8000/liter of double-distilled water. Osmotic potentials were determined using a SC–10 thermocouple psychrometer (Decagon, Pullman, Wash.).

Seeds were primed in 4-cm-diameter polyvinyl chloride columns containing 100 ml of the prepared solutions (Akers and Holley, 1986). Temperature of the osmotica was maintained by using a thermostatically controlled aquarium heater in the water surrounding the columns. Columns were refilled with the osmotic agent as needed. Each 50-seed replication was contained in a nylon mesh bag to prevent seeds from adhering to the sides of the columns. After 7 days, seeds were taken from the priming solutions and rinsed thoroughly under running distilled water for at least 5 min. Mean germination during priming was 26% for –0.6 MPa KNO_3, 2% for –0.8 MPa KNO_3, 1.0% for –1.0 MPa KNO_3, and 4% for –0.5 MPa PEG 8000. Seeds then were blotted dry and placed under a laminar flow hood for 24 h to dry. Seeds of each replication were placed on a 8.7-cm-diameter blue blotter circle (Anchor Paper, St. Paul, Minn.) in 100 × 15-mm polystyrene petri dishes. The seeds then were germinated at 30 ± 1C in a germinating chamber—7 days for KNO_3 treatments and 9 days for PEG 8000. Total percent germination and mean time of germination (MTG) (Rivas et al., 1984) were calculated for each priming treatment: $MTG = T_1N_1 + T_2N_2 + ... + T_nN_n)$/total number of seeds germinated; where T = day number (test initiated on day 0) and N = number of seeds germinated.

Germination response to temperature. Four replications of 50 seeds each were primed (–1.3 MPa KNO_3, 30C for 7 days) and dried as described for the first study. These seeds and four replications of 50 nonprimed seeds were germinated in darkness at 32.2, 30.5, 28.8, 27.6, 26.1, 24.9, 23.4, 21.9, 20.2, or 18.8 ± 0.1C on a thermogradient table (Type DB 2000; van Dok & de Boer, Enkhuizen, NL). Total percentage and MTG were determined as described above.

Results and Discussion

Osmoticum and osmotic potential. Total percent germination increased linearly with decreasing osmotic potential of KNO_3 from 68% at –0.6 MPa to ≥90% at –1.0 MPa or lower, but MTG was unaffected (Table 1). The highest osmotic potential of KNO_3 (–0.6 MPa) resulted in excessive germination (26% ± 8.7%) during priming. Decreasing osmotic potential of PEG 8000 resulted in a linear decrease in total percent germination and a linear increase in MTG (Table 1). The lower total percent germination and longer MTG of PEG-primed seeds compared to KNO_3-primed seeds may be attributed to lower O_2 availability in PEG 8000 (Mexal et al., 1975) or to decreased seed hydration (Alvarado and Bradford, 1988). The highest total germination percentage achieved with PEG-primed seeds (82%) was less than that achieved with –1.3 MPa KNO_3 (95%). Compared to nonprimed seeds, seeds primed in –1.3 MPa KNO_3 had double the total percent germination and one-half the MTG.

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Table 1. Total percent germination and mean time of germination (MTG) of *Rudbeckia fulgida* seeds at 30C after priming (7 days, 30 ± 1C) at various osmotic potentials of KNO_3 or polyethylene glycol (PEG) 8000.

Osmoticum	Osmotic potential (MPa)	Germination Total (%)	Germination MTG (days)
None	---	48	5.9
KNO_3	–0.6	68	2.9
	–0.8	85	2.8
	–1.0	90	2.8
	–1.3	95	3.0
	–1.5	91	3.1
PEG	–0.5	82	3.2
	–0.7	75	4.1
	–1.0	63	4.4
	–1.3	53	5.4
	–1.6	47	6.0
$LSD_{0.05}$(1-way)		20.3	0.9
F test significances			
Osmoticum (OS)		**	**
Osmotic potential (OP)		NS	**
OS × OP		**	**
KNO_3 linear		**	NS
KNO_3 quadratic		NS	NS
PEG linear		**	**
PEG quadratic		NS	NS

NS, ** Nonsignificant or significant at $P \leq 0.01$, respectively.

Germination response to temperature. Total percent germination of primed (–1.3 MPa KNO_3, 30C for 7 days) and nonprimed seeds increased quadratically with increasing temperature, but primed seeds had higher total percent germination than nonprimed seeds at ≥21.9C (Table 2). Priming also increased germination rate. The MTG of primed seeds was an average 2.3 days (43%) lower than that of nonprimed seeds between 24.7 and 32.2C (Table 2). Although MTG varied within this temperature range, the 0.8-day range for primed seeds and 1.2-day range for nonprimed seeds was too small to be of practical significance.

Since the highest total germination percentage of nonprimed seeds occurred at 28.8 to 32.2C (Table 2), which agrees with 30 ± 1C from Fay et al. (1993b), the upper germination temperature recommended in germination guides (Nau, 1989) or seed catalogs (George J. Ball, 1989; G.W. Park Seed Co., 1989–90) for *R. fulgida* should be increased.

Osmotic priming lowered the temperature at which germination was high (Table 2). Such an improvement in germination percentage at low temperatures in response to seed priming has been noted for other species (Carpenter and Boucher, 1991; Pill et al., 1991; Sachs, 1977). Although the total germination percentage of primed or nonprimed seeds was not decreased at the highest germination temperatures relative to lower ones (Table 2), seed priming has increased high-temperature germination percentage of certain species (Atherton and Farooque, 1983; Carpenter and Boucher, 1991; Valdes and Bradford, 1987).

The moisture content of seeds (four replications of 50 seeds each, 104C for 48 h) immediately following priming in –1.3 MPa KNO_3 for 7 days at 30C was 24.7% ± 1.7%, while after drying for 48 h in a laminar flow hood (air flow rate = 1800 $m \cdot s^{-1}$), it was 16.0% ± 2.7%. Thus, primed seeds were able to pass through phase I imbibition more rapidly than nonprimed seeds (moisture = 6.6% ± 0.6%). Accumulation of solutes, enzyme activation, and initiation of metabolic events during controlled seed imbibition (Bewley and Black, 1978) contributed to the increased radicle emergence rate of the primed seeds.

The *R. fulgida* seedlot used in this study had displayed low vigor as monitored by accelerated aging, low-temperature, and conductivity tests (Fay et al., 1993a). Since germination of this seedlot increased 7% by priming in –1.3 MPa KNO_3 (30C for 7 days) following 1 year storage at 23C in sealed plastic containers, priming enhanced the germination of this low-vigor seedlot, a response noted in low-vigor carrot (*Daucus carota*) seeds (Szafirowska et al., 1981).

The results of this study show that osmotic priming of *Rudbeckia fulgida* seed in –1.3 MPa KNO_3 for 7 days at 30C increased their germination rate and percentage at 21.9 to 32.2C. PEG was not a satisfactory priming osmoticum for this species. Germination of primed and nonprimed seeds is optimal between 28 and 32C.

Table 2. Germination percentage and mean time of germination (MTG) of primed and nonprimed *Rudbeckia fulgida* seeds as influenced by germination temperature.

Germination temp (GT) (°C)	Seed treatment (ST) Primed	Nonprimed	Primed	Nonprimed
	Total germination (%)		MTG (days)[z]	
18.8	0	0	---	---
20.2	5	0	---	---
21.9	13	0	3.5	---
23.3	33	1	3.0	---
24.7	66	6	3.2	6.1
26.1	85	21	3.2	4.9
27.6	95	50	2.8	5.0
28.8	93	70	2.9	5.2
30.5	94	77	3.0	5.6
32.2	92	72	3.6	5.8
$LSD_{0.05}$(2-way)	8.4		0.6	
F test significances				
GT	**		**	
ST	**		**	
GT × ST	**		**	
GT linear	**	**	**	NS
GT quadratic	**	**	**	NS

[z]--- = Low germination percentage precluded calculation of MTG.
NS, ** Nonsignificant or significant at $P \leq 0.01$, respectively.

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