Solid Matrix Priming Hastens Canterbury Bells Seed Germination

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SUMMARY. **Canterbury bells (*Campanula medium* 'Champion Blue') seeds were primed using calcined clay at 68 °F (20 °C) for 1, 3, or 5 days at water potentials (Ψ) of –25, –20, –18, or –16 bars (–2.5, –2.0, –1.8, or –1.6 MPa). Germination was fastest (3.0 to 3.1 days) after priming with a Ψ of –18 or –16 bars for 5 days. Seeds primed for 3 or 5 days with moisture present germinated faster than nonprimed seeds, but time to 50% germination (T_{50}) was longer when seeds were primed for 1 day regardless of Ψ compared to nonprimed seed. Germination uniformity decreased (time from 10% to 90% germination, T_{10-90}, increased) as Ψ increased. Although a curvilinear relationship existed between T_{10-90} and priming duration, T_{10-90} did not differ between nonprimed seeds and seeds in any priming treatment except those primed for 3 days with 20% moisture (–16 bars). Priming did not affect total germination percentage (97%).**

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Canterbury bells is a biennial plant commonly used in gardens in the United States and sold as a flowering potted plant in Europe (Dole and Wilkins, 1999). Flowers are predominately blue or lavender, but they can also be white or pink. The inflorescence is a raceme of cup-shaped flowers creating an unusual overall shape. 'Champion Blue' was bred specifically for cut flower production. It has a short crop time, typically flowering in 16 to 20 weeks, making it possible to grow and sell flowers from this normally biennial plant in a cost effective time period (Cavins, 1999). Canterbury bells seeds generally require 6 to 12 d at 68 °F to germinate (Association of Official Seed Analysts, 1998); however, variable germination rates make production difficult and reseeding is often necessary.

Seed priming can enhance germination of direct-seeded plants and improve stand establishment. Priming is defined as a presowing seed treatment to enhance germination rate and percentage (Parera and Cantliffe, 1994). By shortening the time needed for initial stand establishment, priming may improve seedling uniformity and reduces seedling exposure to soil crusting (Bennett et al., 1992), soilborne pathogens (Bennett et al., 1992; Conway et al., 2001), and unfavorable temperatures (Bennett et al., 1992). Growth and development of seedlings from primed seed are indistinguishable from that of untreated seed except under stressful conditions (Parera and Cantliffe, 1994; Osburn and Schroth, 1989).

In priming, the hydration level of the seed is manipulated to allow pregerminative processes to begin, but germination is halted before radicle emergence. Primed seed may be dried and stored for planting at a later date. Thus, the time required for germination and emergence is shortened. Osmotic seed priming commonly uses inorganic salt solutions or polyethylene glycol solutions (Bradford, 1986). Solid matrix priming combines seeds, water, and either an organic or inorganic solid material at a certain temperature for a predetermined time period (Parera and Cantliffe, 1994). Water is adsorbed to the solid material to create a low (hypertonic) matric potential, thus regulating seed water uptake. Compared to other priming techniques solid matrix priming is inexpensive and can be used for large quantities of seed (Khan, 1992). Khan (1992) and Pill et al. (1997) suggest that rather than separating primed seed from the matric material, primed seed may be sown with the matric material. This would be beneficial for planting species with extremely small seeds, such as canterbury bells [about 22,500 seeds/oz (800 seeds/g)]. Previous trials using aerated osmotic priming were unsuccessful with canterbury bells because seeds were difficult to recover after priming, even when enclosed in a nylon mesh bag (T.L. Bosma, unpublished).

The purpose of this study was to determine if solid matrix priming could decrease germination time and increase germination uniformity and total germination percentage of 'Champion Blue' canterbury bells seeds.

Materials and methods

Seeds of 'Champion Blue' canterbury bells (Sakata Seed America, Morgan Hill, Calif.) were subjected to solid matrix priming by placing 50 seeds in a 2 × 3-inch (5 × 8 cm) polyethylene zip bag filled with calcined clay (Super Absorbent, pH 7.0; Balcones Mineral Corp., Flatonia, Texas) at a weight ratio of 1:40 (seed:calcined clay). Calcined clay particles were ground to pass through a 35-mesh (500-mm) screen and had a density of 0.3 oz/inch^3 (0.6 g·L^{-1}). Calcined clay was oven dried at 171 °F (77 °C) for 24 h then stored for no more than two weeks in a sealed polyethylene zip bag until use. This drying temperature also insured that the calcined clay was not contaminated with microorganisms. Super Absorbent was chosen for priming based on previous research (Mereddy et al., 2000).

Deionized water was placed in bags at 0%, 10%, 15%, or 20% (vol/wt) of the seeds plus calcined clay and mixed, resulting in a Ψ of –25, –20, –18, and –16 bars, respectively. The relationship between Ψ and moisture content on a weight basis was determined for the calcined clay. Water potential was measured with a chambered in situ psychrometer (Merrill Specialty Equipment, Logan, Utah) coupled with a psychrometer microvoltmeter (Wescor HP-115; Wescor, Inc., Logan, Utah). The equipment was calibrated against potassium

chloride standards. Calcined clay Ψ was determined three times with three replications before analysis.

During priming, bags were stored upright in an environmental growth chamber (model 1-35LL; Percival Manufacturing Co., Boone, Iowa) for 1, 3, or 5 d at 68 °F (20 °C) with cool white fluorescent lighting [photosynthetic photon flux (PPF) = 20.7 $mmol \cdot m^{-2} \cdot s^{-1}$], as specified by the Association of Official Seed Analysts (1998) for canterbury bells seed. Previous tests revealed that canterbury bells seeds primed for more than 5 d or at greater than 20% moisture content (–16 bars) in the calcined clay germinated during priming (T.L. Bosma, unpublished). Immediately after removal from the chamber, seeds were separated from the calcined clay by allowing the calcined clay to pass through a 35 mesh screen. Seeds were air-dried on paper towels for 24 h. Seeds then were placed in 3.5-inch (9-cm) diameter petri dishes lined with two pieces of 3.5-inch diameter Whatman no. 1 filter paper at 73 °F (23 °C) with cool white fluorescent lighting (PPF = 20.7 $mmol \cdot m^{-2} \cdot s^{-1}$). Deionized water [0.1 fl oz (2 mL)] was added daily as needed. The number of seeds germinated was counted daily at 1600 HR for 16 d. Seeds were considered germinated when the radicle had penetrated the seed coat and was visible to the naked eye. Germinated seeds were removed from the petri dishes and discarded. Nonprimed seed germinated in distilled water served as the control. Germination time [days to 50% of final germination (T_{50})] for each treatment and replication was calculated as described by Orchard (1977) while germination uniformity [days from 10% to 90% germination (T_{10-90})] was calculated as described by Wu et al. (1999). Total germination percentage was calculated for each treatment and replication using the equation: percent germination = (number of seeds germinated/number of seeds tested) × 100.

A completely randomized design with four replications of 50 seeds each was used. Data were analyzed using the general linear model procedure (SAS Institute, Inc., Cary, N.C.) and trend analyses were performed on significant main effects and interactions (Snedecor and Cochran, 1980). An arcsin transformation was used for percentage data prior to statistical analysis. Differences in germination rate and uniformity between seeds in priming treatments and nonprimed control seeds were determined using *t* tests.

Seed viability of nonprimed seed was determined by placing 50 seeds in each of two 3.5-inch diameter petri dishes containing a 3.5-inch diameter Whatman no. 1 filter paper moistened with deionized water. Room temperature was maintained at 73 to 79 °F (23 to 26 °C) with constant fluorescent light (PPF = 80 $mmol \cdot m^{-2} \cdot s^{-1}$). Seed viability was 99%.

Results

Moisture content interacted with priming duration for T_{50} (Table 1). A decreasing cubic relationship existed between T_{50} and matrix moisture content when seeds were primed for 3 or 5 d, but no significant trend between T_{50} and moisture content existed for seeds primed for 1 d. Seeds primed for 1 d regardless of matrix moisture content had larger T_{50} values than nonprimed seeds (Table 1). Seeds primed for 3 d at –25 bars did not differ in T_{50} from nonprimed seeds; however, seeds receiving 3 d of priming with –18, –20, or –25 bars moisture and seeds receiving 5 d of priming regardless of moisture content had smaller T_{50} values than nonprimed seeds.

Moisture content did not interact with priming duration for T_{10-90} (Table 2). A curvilinear relationship between priming duration and T_{10-90} existed. The T_{10-90} of seeds primed for 3 d with –25 bars moisture was larger (4.4 d) than for nonprimed control seeds (3.1 d). The T_{10-90} increased linearly as matrix moisture content increased. The T_{10-90} did not differ between seeds in any other priming treatment and nonprimed seeds.

Neither moisture content nor priming duration affected total germination percentage, which averaged 97%.

Discussion

Although the total germination percentage of canterbury bells seeds was high and unaffected by solid matrix priming, variable germination rates and subsequent lack of uniformity make commercial production difficult. Solid matrix priming for 3 or 5 d decreased T_{50} resulting in faster germination compared to the nonprimed control. Pill et al. (1997) had similar results when priming kentucky bluegrass (*Poa pratensis*) and tall fescue (*Festuca arundinacea*) for 4 d at –15 bars (–1.5 MPa). At a seed:vermiculite ratio of 1:40, total germination percentage and T_{10-90} were not affected, but T_{50} was 2 d faster than the nonprimed control for kentucky bluegrass. The T_{50} for primed tall fescue was about 3 d faster than for nonprimed seed. The T_{50} of native perennial grasses receiving matric priming and germinated at low temperatures [50 °F (10

Table 1. Number of priming days, priming medium moisture content, and time to 50% germination (T_{50}), of canterbury bells 'Champion Blue'. Values are means of four replications of 50 seeds.

Priming duration (PD) (d)	Moisture content (MC) (%)	Ψ (bars)[z]	Germination time (T_{50}) (d)
Nonprimed	---	---	5.3
1	0	–25	6.2***
	10	–20	6.0**
	15	–18	6.0**
	20	–16	5.7*
3	0	–25	5.2NS
	10	–20	4.8*
	15	–18	3.7***
	20	–16	4.4***
5	0	–25	4.8*
	10	–20	4.2***
	15	–18	3.1***
	20	–16	3.0***
Significance			
PD (1 d) × MC			$L^{NS}Q^{NS}C^{NS}$
PD (3 d) × MC			$L^{***}Q^{*}C^{***}$
PD (5 d) × MC			$L^{***}Q^{NS}C^{**}$

[z]1 bar = 0.1 MPa.

NS,*,**,***Nonsignificant or significantly different than nonprimed seed at $P \leq 0.05$, 0.01, or 0.001, respectively; L = linear, Q = quadratic, C=cubic.

Table 2. Number of priming days, priming medium moisture content, and time from 10% to 90% (T_{10-90}) germination of canterbury bells 'Champion Blue'. Values are means of four replications of 50 seeds.

Treatment	Germination time (T_{10-90}) (d)
Nonprimed	3.1
Priming duration (PD)[z]	
1 d	3.1
3 d	3.5
5 d	2.8
Linear	NS
Quadratic	*
Moisture content (MC)[z]	
0% (–25 bars)[y]	2.4
10% (–20 bars)	3.1
15% (–18 bars)	3.4
20% (–16 bars)	3.6
Linear	***
Quadratic	NS
Cubic	NS
Significance (*P*)	
PD	0.0269
MC	0.0009
PD × MC	NS

[z]Moisture content refers to the percentage of moisture in the calcined clay (wt/vol) and the total water potential of the calcined clay. 1 bar = 0.1 MPa.
[NS,*,***]Nonsignificant or significant at $P \leq 0.05$ or 0.001, respectively.

°C)] also improved for each species and priming duration tested (Hardegree, 1994). The T_{50} for seeds of bottlebrush squirreltail (*Sitanion hystrix*) primed at 70 °F (25 °C) with a Ψ of –15 bars was reduced by 3 d compared to nonprimed seeds.

In our study, priming for 1 d regardless of matrix moisture content slowed T_{50} by about 1 d compared to the nonprimed control. Hardegree and Emmerich (1992) noted that matric priming for 48 h at Ψ more negative than –16 bars was sometimes detrimental to germination relative to control treatments. Our Ψ ranged from –16 bars with 20% moisture to –25 bars with 0% moisture. The lower T_{50} in seeds primed for 1 d compared to nonprimed seeds may be explained by low Ψ, but apparently seeds primed for 3 or 5 d were not affected by the low Ψ since they germinated more quickly than the nonprimed control seeds.

Regardless of matrix moisture content, seeds primed for 5 d germinated faster (had lower T_{50} values) than those primed for 1 or 3 d (Table 1). Hardegree (1994) also found that increasing matric priming duration reduced germination time. In that study, priming for 8 d consistently produced T_{50} values lower than those produced with 2 d of priming.

Germination uniformity decreased (T_{10-90} increased) with increased moisture in the priming medium, which is not beneficial for commercial production. Although a curvilinear relationship existed between priming duration and T_{10-90}, the T_{10-90} was generally similar for primed and nonprimed seed. Various methods of priming have improved germination uniformity in other species (Brocklehurst and Dearman, 1983; Haigh and Barlow, 1987).

From this study, we recommend solid matrix priming of canterbury bells 'Champion Blue' seeds for 5 d at 15% or 20% matrix moisture content (–18 or –16 bars, respectively) and 68 °F to reduce germination time.

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