Enhanced Celery Germination at Stress Temperature via Solid Matrix Priming

Carlos A. Parera, Ping Qiao, and Daniel J. Cantliffe

Vegetable Crops Department, Institute of Food and Agricultural Science, University of Florida, Gainesville, FL 32611

Additional index words. *Apium graveolens*, seed disinfection, high temperature, sodium hypochlorite

Abstract. To alleviate high-temperature-induced reductions in seed germination, emergence, and seedling uniformity in celery (*Apium graveolens* L.), seeds were primed via solid matrix priming (SMP); 0.5 g celery seeds was incubated at 15°C with 10 g calcined clay and 2 ml water. After 2 days, 1, 2, 3, or 4 ml water or 1% NaOCl solution was added and seeds were kept for 2, 4, 6, 8, 10, 12, and 14 additional days. The germination percentage and coefficient of germination velocity (COV) were calculated for each treatment at 15 and 30°C. The seeds primed with NaOCl gained significantly less moisture after 8 days of priming than those treated with water, regardless of the volume added. Germination of nonprimed seeds was 83% and 2% at 15 and 30°C, respectively. Final germination at 30°C increased to >80% when seeds were primed with 3 or 4 ml NaOCl solution or 3 ml water for >10 days. SMP treatment significantly reduced the negative effect of high temperature on celery seed germination.

Poor germination, emergence, and seedling uniformity are common in celery cultivars sown at temperatures >18 to 20°C (Brocklehurst et al., 1983; Tanne and Cantliffe, 1989). The detrimental effects of high temperature on celery germination have been studied extensively (Thomas et al., 1975). Many presowing seed treatments to improve celery germination and seedling uniformity have been suggested. Thomas (1983) reported higher germination percentage and faster germination when celery seeds were soaked in a combined solution of gibberellin (A/A₁) and (2-chloroethyl)phosphonic acid (ethephon) at low temperature. The combination of seed priming and growth regulators resulted in an improved germination rate and total germination of celery (Brocklehurst et al., 1983; Tanne and Cantliffe, 1989). However, these treatments had little effect on the rate and total germination at temperatures >25°C.

Solidmatrix priming (SMP) is a presowing technique that uses a solid as an osmoticum. This technique has been used to improve seed germination and rate in many species (Kubik et al., 1988; Parera and Cantliffe, 1990; Taylor et al. 1988). Sodium hypochlorite has been reported as an effective seed disinfectant (Elmer and Stephens, 1988; Fieldhouse and Sasser, 1975). Taylor (1949) combined water soaking and NaOCl addition to increase germination rate in celery. Lettuce (*Lactuca sativa* L.) seed them-to-inhibition was diminished by NaOCl addition (Drew and Brocklehurst, 1984). Parera

and Cantliffe (1991) reported an increase in final germination and seedling vigor of supersweet corn (*Zea mays* L.) when seeds were primed via SMP combined with NaOCl.

The objective of this investigation was to determine the effect of SMP and NaOCl as presowing treatments on rate and final germination percentage of celery at 15 and 30°C.

'M-68-29-5' celery seeds were obtained from Sunseeds Genetics, Hollister, Calif., and stored at 15°C and 45% relative humidity (RH)

Table 1. Analysis of variance mean squares for moisture content in celery seeds during priming.

Source	df	Seed moisture	
		Mean square	F
Time (T) ^z	7	4,855	40**
Rep/T (Error a)	24	121	
Milliliter (M) ^y	3	21,663	1,155**
Solution (S) ^x	1	2,241	119**
T × M	21	1,099	59**
T × S	7	86	5**
M × S	3	904	48**
T × M × S	21	66	4**
Error b	168	19	
cv (%)	12.6		

^zDays of priming.

^yMilliliters of water or 1% NaOCl solution.

^xWater or 1% NaOCl solution.

**Significant at $P = 0.01$.

in darkness. The SMP treatment consisted of placing 0.5 g seeds (≈1000 seeds), 10 g calcined clay (Emathlite, Mid-Florida Mining, Lowell, Fla.), and 2 ml distilled water in a 250-ml container (Filtunit, Nalgene, Rochester, N.Y.) (Parera and Cantliffe, 1991). The containers were incubated at 15°C in light (15 $\mu\text{mol}\cdot\text{s}^{-1}\cdot\text{m}^{-2}$) under continuous rotation (0.22 rpm) in a rotator (Lab-Line Instruments, Melrose Park, Ill.). After 2 days of incubation, 1, 2, 3, or 4 ml distilled water or NaOCl solution (1%, v/v) was added to each container. Priming continued for an additional 2, 4, 6, 8, 10, 12, or 14 days under the same conditions. Moisture content of seeds was measured at each priming time and for each solution amount and treatment. A 25-seed sample was dried at 85°C for 48 h and moisture content was expressed on a dry-weight basis.

After each treatment, the seeds were dried at 15°C and 20% RH to a 4.7% moisture content and stored no longer than 1 month as noted above. Four replications of 25 nonprimed or

Fig. 1. Final germination percentage of celery seed primed with water via solid matrix priming and germinated at 15°C. Mean separation by priming time using Duncan's multiple range test, $P = 0.05$; Nontreated seeds germinated, 83%. Water was added at 1, 2, 3, or 4 ml.

Received for publication 10 Feb. 1992. Accepted for publication 3 Sept. 1992. Univ. of Florida, Agricultural Experimental Station Journal Series no. R-02004. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper must therefore be hereby marked advertisement solely to indicate this fact.

Table 2. Moisture content of celery seeds during priming when 1, 2, 3, or 4 ml water or 1% NaOCl solution was added.

		Moisture content of seed (%)				
		Milliliter ^z				
Solution	Time ^y	1	2	3	4	LSD
NaOCl	2	19.9	19.8	20.1	19.5	2.2
Water		19.5	20.2	19.6	20.0	1.2
		NS	NS	NS	NS	
NaOCl	4	23.9	22.8	59.8	87.7	8.6
Water		24.7	32.4	68.5	92.7	10.2
		NS	NS	NS	NS	
NaOCl	6	21.1	26.4	48.7	86.8	7.5
Water		22.2	27.1	57.5	96.3	3.4
		NS	NS	*	*	
NaOCl	8	18.7	22.1	38.6	69.4	5.5
Water		20.4	24.6	49.4	87.7	5.7
		*	**	*	**	
NaOCl	10	17.3	21.9	26.4	50.9	9.8
Water		17.5	22.5	36.9	80.1	6.2
		NS	NS	*	**	
NaOCl	12	16.9	20.9	24.6	40.9	10.1
Water		16.3	20.6	28.2	71.1	7.8
		NS	NS	NS	*	
NaOCl	14	15.6	18.0	23.1	31.8	5.8
Water		15.3	19.5	26.9	56.8	9.6
		NS	NS	NS	*	
NaOCl	16	13.8	17.9	20.5	22.8	3.5
Water		13.9	17.6	24.5	36.6	4.5
		NS	NS	NS	**	

^zMilliliters of water or 1% NaOCl solution added 2 days after priming.

^yDays of priming.

NS, *, **Nonsignificant or significant at $P = 0.5$ or 0.01 , respectively.

primed seeds were germinated in 5-cm petri dishes on two layers of Whatman no. 1 filter paper soaked with 1.5 ml distilled water, then placed in incubators set at 15 or 30C with $23 \mu\text{mol}\cdot\text{s}^{-1}\cdot\text{m}^{-2}$ light. Germination was recorded daily and counted when the radicle became visible. Percentage of germination and coefficient of germination velocity (COV) (Scott et al., 1984) were calculated. The experiments were conducted as a randomized complete-block design with four replications. The data were subjected to analysis of variance on a split-block experimental design, with priming time as a main block. Percentage data were arcsin-transformed before analysis of variance was conducted.

Since there were significant interactions among solution type, time, and quantity (Table 1), the main effects for moisture content were analyzed separately. Seeds primed with 1 or 2 ml of water had significantly more moisture after 8 days of priming than seeds primed with 1% NaOCl solution (Table 2). The seeds primed with 3 ml NaOCl for 6 to 10 days and those primed with 4 ml NaOCl for 6 to 16 days gained less moisture than seeds primed with water. After 14 days of priming, the seeds primed with 4 ml water contained almost twice as much moisture as seeds primed with the same volume of 1% NaOCl solution. The lower osmotic potential of the NaOCl solution (-1.28 MPa) compared with the water's (-0.02 MPa) could explain the differences observed between the treatments. The moisture content of the seeds rapidly increased during the first 4 days of priming, then gradually decreased to 20% to 30% at 16 days of priming.

At both germination temperatures, the in-

teractions among priming time, solution amount, and solution type were significant for germination percentage (Table 3) and COV (data not shown). The main effect of solution amount was separated and analyzed for each priming time and solution type. The final germination percentage of nontreated 'M-68-29-5M' celery seeds was severely inhibited by high temperature. Only 2% of the nonprimed seeds germinated at 30C compared with 83% at 15C. There were no significant differences in germination at 15C when 1, 2, 3, or 4 ml NaOCl solution was added to the solid osmoticum for various priming periods (range 80% to 95%). However, when 4 ml water was used, there was a significant decline in germination percentage after 4 days of priming (Fig. 1). Ideal conditions for pathogen growth and development [(higher moisture content

(90%) in the seeds], precocious seed germination in the container during priming, or both may have contributed to the lower germination rate observed. Although adding 4 ml NaOCl led to relatively high seed moisture content, NaOCl would be expected to prevent fungal growth.

At 30C, 4 or 6 days of priming with 3 and 4 ml NaOCl, respectively, or 8 days with 3 ml water significantly increased final germination percentage (Fig. 2) and COV (data not shown). The highest germination percentage ($>80\%$) was reached at 30C when 3 or 4 ml of NaOCl solution and 8 to 16 days of incubation were used. When water was used instead of NaOCl solution, the combination of 3 ml water and 10 to 16 days incubation (Fig. 2) gave the highest final germination percentage. Similar to the experiment at 15C, 4 ml water did not improve germination at 30C. The moisture content of the seeds when 1 or 2 ml of water or NaOCl was used might not have been enough to start or continue the priming (germination) process; thus, no effect on germination was observed at 30C at these two moisture levels.

Before radicle protrusion, the celery embryo must at least double its size. The embryo of primed celery seeds has been shown to increase to almost twice its size after priming with osmotic solutions (Karssen et al., 1989). Sodium hypochlorite reduced thermo-inhibition in lettuce seeds by weakening the pericarp (Drew and Blocklehurst, 1984). The most effective treatments when the seeds were germinated at high temperature (30C) were 1) SMP priming for 10 to 16 days with 3 or 4 ml 1% NaOCl solution, and 2) SMP priming with 3 ml water. The combination of embryo growth during SMP and pericarp weakening by a long incubation period, NaOCl addition, or both may have increased total germination and germination rate of celery at high temperature after SMP treatment.

Literature Cited

- Brocklehurst, P.A., W.E. Rankin, and T.H. Thomas. 1983. Stimulation of celery seed germination and seedling growth with combined ethephon, gibberellin and polyethylene glycol seed treatments. *Plant Growth Regulat.* 1:195-202.
Drew, R.L. and P.A. Brocklehurst. 1984. Investiga-

Table 3. Analysis of variance mean squares for germination percentage at 30 and 15C in celery seeds after priming.

Source	df	Temp			
		30C		15C	
		Mean square	F	Mean square	F
Time (T) ^y	7	1.0239	19**	0.1668	4**
Rep/PT (Error a)	24	0.0524		0.0248	
Milliliter (M) ^z	3	4.4985	193**	2.6463	129**
Solution (S) ^z	1	0.8746	80**	3.0387	149**
T × M	21	0.3118	13**	0.1579	8**
T × S	7	0.1003	4**	0.1319	7**
M × S	3	0.9088	39**	2.4531	120**
T × M × S	21	0.1225	5**	0.1531	8**
Error b	168	0.0232		0.0204	
cv (%)		39.8		12.8	

^yDays of priming.

^zMilliliters of water or 1% NaOCl solution.

*Water or 1% NaOCl solution.

**Significant at $P = 0.01$.

Fig. 2. Final germination percentage of celery seed primed via solid matrix priming using (A) 1% NaOCl or (B) water and germinated at 30C. Mean separation by priming time using Duncan's multiple range test, $P = 0.05$; Nontreated seeds germinated, 2%.

tions on the control of lettuce seed germination at high temperature. *J. Expt. Bot.* 35:986-983.

Elmer, W.H. and C.T. Stephens. 1988. Comparison of technique for eliminating contaminants from asparagus seeds. *HortScience* 23:231-232.

Fieldhouse, D.J. and M. Sasser. 1975. Stimulation of pepper seed germination by sodium hypochlorite. *HortScience* 10:622.

Karssen, C.M., A. Haigh, P. van der Toorn, and R. Weges. 1989. Physiological mechanisms involved in seed priming, p. 269-280. In: R.B. Taylorson (ed.). *Recent advances in the development and germination of seeds*. Plenum, New York, N.Y.

Kubik, K.K., J.A. Eastin, J.D. Eastin, and K.M. Eskridge. 1988. Solid matrix priming of tomato and pepper. *Proc Intl. Conf. Stand Establishment for Hort. Crops*, Lancaster, Pa. p. 86-89.

Parera, C.A. and D.J. Cantliffe. 1990. Improved stand establishment of *sh2* sweet corn by solid matrix priming and seed disinfection treatments. *Proc. Intl. Conf. Stand Establishment for Hort. Crops*, St. Paul, Minn. p. 91-98.

Parera, C.A. and D.J. Cantliffe. 1991. Improved germination and modified imbibition of *shrunk-2* sweet corn by seed disinfection and solid matrix priming. *J. Amer. Soc. Hort. Sci.* 117:400-403.

Scott, S.J., R.A. Jones, and W.S. Williams. 1984. Review of data analysis methods for seed germination. *Crop Sci.* 24:1192-1198.

Tanne, I. and D.J. Cantliffe. 1989. Seed treatments to improve rate and uniformity of celery seed germination. *Proc. Fla. State Hort. Soc.* 102:319-322.

Taylor, A.G., D.E. Klein, and T.H. Whitlow. 1988. SMP: Solid matrix priming of seeds. *Scientia Hort.* 37:1-11.

Taylor, C.A. 1949. Some factors affecting germination of celery seeds. *Plant Physiol.* 24:93-102.

Thomas, T.H. 1983. Stimulation of celeriac and celery seed germination by growth regulator seed soaks. *Seed Sci. & Technol.* 11:301-305.

Thomas, T.H., D. Palevitch, N.L. Biddington, and R.B. Austin. 1975. Growth regulators and the phytochrome mediated dormancy of celery seeds. *Physiol. Plant.* 35:101-106.