Optimal Priming Conditions and Persistence of Enhanced Emergence in Osmotically Primed Sugarbeet Seed

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ABSTRACT

Osmotic priming often improves emergence rates and stands of direct-seeded vegetable crops, and may make the difference between sub-optimal and acceptable final stand for achieving maximum yield potential. However, optimal priming treatment can vary with species and perhaps cultivars. Inclement weather may delay planting after priming, thus, the influence of storage conditions on priming retention must be determined. To determine optimal priming conditions at 22 to 24°C and deterioration of primed seed during storage, monogerm sugarbeet seed balls (*Beta vulgaris* cv WS-88) were treated for 1 to 5 days with solutions containing 100, 200, or 300 g/L polyethylene glycol 8000 (PEG) and stored at 6 or 24°C for up to 6 weeks and emergence assessed in the greenhouse. Water potentials of the PEG solutions were calculated as -0.13, -0.62, and -1.72 MPa, respectively. The time required to reach 50% of maximum emergence (T_{50}) declined in linear fashion with increasing days of treatment in PEG. Total emergence was greatest in seeds treated with 300 g/L PEG for 3 days, but declined with longer treatment durations. Sprouting was observed during priming in seeds treated with 100 g/L PEG for 2 or more days, and in seeds treated with 200 g/L PEG for 3 or more days. Treatment in 300 g/L PEG for 3 days at room temperature was judged optimal for this sugarbeet cultivar. After osmoconditioning, T50 increased 0.05 days per week of storage whether stored at 6 or 24°C, but remained below that of untreated seed for the 6-week storage period. Maximum emergence of primed seed was equal to or above emergence from untreated seed throughout the storage period.

Additional Key Words: *Beta vulgaris* L., osmoconditioning, polyethylene glycol

Yield and quality of direct-seeded vegetable crops are greatly influenced by the speed, uniformity, and percentage of emergence. Greatest profit is realized when maximum yield and quality is achieved with minimal input costs. To this end, sugarbeet growers in southern Idaho increasingly are planting to achieve a desired final stand without thinning (D. Traveller, 1985, personal communication). Highest sugarbeet yield potential is obtained by establishing 37,000 to 74,000 seedlings per hectare as early in the spring as possible. Sub-optimal stands may out-yield a better stand of later- established beets. Field emergence is generally 60-70% of seed planted. However, the exact ratio of established seedlings to seeds planted can't be predicted due to the effects of uncontrolled stresses such as cold temperatures, excessive moisture, diseases, and soil crusting. Numerous pre- plant seed treatments for reducing mortality in emerging seedling populations have been investigated. One of the most successful and widely used treatments is osmotic priming.

Priming of table and sugarbeet seed (*Beta vulgaris* L.) has reduced seedling mortality in field trials when *Pythium* spp. (Baker & Rush, 1989), suboptimal temperature (Khan et al., 1983), suboptimal moisture (Durrant et al., 1983b), or soil crusting (Sale and Harrison, 1974) limit seedling establishment. Yield and quality of sugarbeets may be enhanced by priming if primed seeds established more optimal or more uniform plant populations compared to unprimed seeds (Khan et al., 1983). In the absence of stresses affecting seedling establishment, priming is not expected to improve sugarbeet yields.

The results of priming among species, varieties, and seedlots have been variable (Heydecker, 1977). Because of this variability in response, Bradford has suggested that treatment conditions must be optimized for each seedlot (Bradford, 1986). However, maximum priming can be achieved in a particular seedlot through various combinations of temperature, water potential, and treatment duration. Maximum priming of `Bush Mono G' sugarbeet seeds was accomplished at temperatures from 15 to 22°C in solutions with water potentials from -1 to -2 MPa and treatment durations of 4 to 7 days (Durrant et al., 1983a). Thus it may be possible to select a convenient temperature and water potential for priming all seedlots of a particular cultivar, with optimal duration to be determined experimentally. Whether or not treatment duration must be adjusted to maximize the priming response for each seedlot within a cultivar has not been demonstrated. Reports of optimal priming conditions for sugarbeet cultivar WS-88 (which comprises approximately 60% of total sugarbeet acreage in Idaho) were not found.

The deterioration rate of primed seed is of interest, because planting may be delayed due to unfavorable weather.

Germination of untreated sugarbeet seed deteriorated at a rate of 9% per year at 10°C in open containers (Longden and Johnson, 1974). Onion seed retained the beneficial effects of priming for 18 months at 10°C and 9% moisture (Dearman et al., 1986). Similarly, primed tomato seed was stored at 20°C or lower and 6% moisture for 18 months without loss of priming effects (Alvarado & Bradford, 1988). Reports of retention of priming effects during storage of sugarbeet seed have not been found.

Our objectives were to determine the optimal polyethylene glycol 8000 (PEG) concentration and treatment duration for priming monogerm sugarbeet seed (*Beta vulgaris* `WS-88') at 22 to 24°C, and to measure the persistence of priming responses after 6 weeks of storage at 6 or 24°C.

MATERIALS AND METHODS

Priming Experiments 1 and 2.

Sugarbeet seeds of cultivar WS-88 were treated with solutions of 100, 200, or 300 g/L of polyethylene glycol 8000 (PEG) for 1 to 5 days at 22 to 24°C in experiment 1. From Michel's equation No. 4, solution water potentials were calculated as -0.13, -0.62, and -1.72 MPa for 100, 200, and 300 g/L PEG solutions, respectively (Michel, 1983). Fifty seeds were placed on a pair of 2.175 g blotters which were saturated with 10 ml of PEG solution. This volume allowed a thin film of solution to remain on the surface of the blotter. Because cellulose fibers may absorb water while excluding PEG, water potentials experienced by seeds were probably lower than those of the original solutions. Using the equations of Hardegree and Emmerich, we calculated water potentials experienced by the seeds as -0.20, -1.14, and -2.21 MPa for 100, 200, and 300 g/L PEG solutions, respectively (Hardegree and Emmerich, 1990). Blotters of seeds were contained in 9cm square petri dishes and sealed with Parafilm (American National Can, Greenwich, CT). Seeds were removed from the petri dishes after PEG treatment, and the number of seeds with visible radicles was determined. Seeds were then rinsed in distilled water to remove PEG, spread on toweling, and air dried for 24 h to original seed moisture (6 g/kg). Sugarbeet seeds rinsed and dried in this manner lost about 15% moisture in the first hour. Thereafter, moisture was lost at a rate of 2 to 3% /hr. After drying to original seed moisture, seeds from each petri dish were divided into 5 lots of 10 seeds. Each lot was planted 1 cm deep into a 10 cm diameter pot containing commercial 'Sunshine' potting mix (Fisons Horticulture, Inc., Vancouver, B.C.). Pots were placed on a greenhouse bench in a randomized complete block design with five replicates, watered as needed, and emergence was recorded daily for 13 days after planting. The initiation of PEG treatments was staggered in time to allow simultaneous planting of seed

from all durations of treatment. Five pots, each containing 10 untreated seeds, were included as controls. The entire experiment was repeated as described in experiment 1 except that seeds were treated only with a 300 g/L PEG solution for 1 to 5 days.

The time required to reach 50% of total emergence (T_{50}) was calculated by linear interpolations for each replicate of the specified treatments in both experiments with the two daily emergence observations that bracketed the T_{50} value. Variances of T_{50} and total emergence were analyzed separately for the two experiments and found to be homogeneous using the F-test. The results of experiment 2 and the 300 g/L PEG treatments from experiment 1 were combined and analyzed as a randomized complete block with replicates within experiments as blocks and experiments and days of PEG treatment as main effects. Single degree of freedom contrasts were included in the model to test for linear, quadratic, and cubic trends. When significant linear, quadratic, or cubic trends were found, the response was modeled with a regression polynomial of an appropriate order.

Storage Experiments 3 and 4.

To assess the effects of storage on priming, sugarbeet seeds were treated with 300 g/L PEG for 3 days (the optimal treatment as determined by preliminary experiments and confirmed in experiments 1 and 2), packaged in coin envelopes, and stored at either 24 or 6°C for 1 to 6 weeks. Relative humidities in the 24 and 6°C storage environments averaged 43.4 and 90.0%, respectively. After storage, emergence tests were conducted in the greenhouse as described for experiments 1 and 2. An untreated control and a freshly primed (unstored) check also were included in the emergence test. Experiment 4 was a duplicate of experiment 3 except for use of a different seed lot of the same cultivar. Results of experiments 3 and 4 were analyzed separately, and variances were found to be homogeneous with an F-test. Total emergence and T_{50} values from experiments 3 and 4 were combined and analyzed as randomized complete block designs with replicates within experiments as blocks, and experiments, weeks of storage, and storage temperatures as main effects. Contrasts for linear, quadratic, and cubic trends were included in the analyses. When significant trends were found, the response was modeled with a regression polynomial of an appropriate order.

RESULTS AND DISCUSSION

Priming Experiments 1 and 2.

Sprouting was observed in seeds soaked in 100 g/L PEG for 2 or more days, and in seeds soaked in 200 g/L PEG for 3 or more days. No sprouting was observed in seeds soaked in 300 g/L

PEG for up to 5 days. Sprouting also has been observed during priming treatments with `Bush Mono G' sugarbeet seed in -1.5 MPa solutions at 22°C and in -0.5 and -1.0 solutions at 15°C (Durrant et al., 1983a). Because sprouting is considered an undesirable result, the 100 and 200 g/L PEG treatments were not included in the analysis.

In both experiments the duration of treatment in 300 g/L PEG had a significant ($P = 0.05$) linear effect on T_{50} (Fig. 1a). Contrasts testing for quadratic and cubic trends in the response were not significant. Regression analysis for T_{50} showed that days of treatment and the interaction of days of treatment with experiment were significant elements in the model (Table 1). Values for T_{50} continued to decrease with increasing treatment time, although the rate of decrease was different in the two experiments (Fig. 1a), and resulted in a significant duration of treatment by experiment interaction. Because greenhouse temperatures were not precisely controlled, temperature differences may account for different emergence rates in the two experiments. Increasing the priming treatment duration at 15°C also lowered T_{50} of `Bush Mono G' sugarbeet seeds (Durrant et al., 1983a) to a minimum value, beyond which either sprouting occurred or T_{50} increased, depending on the water potential of the priming solution. At 22°C, however, T_{50} continued to decline with increasing treatment duration, reaching an asymptotic minimum in about 20 days. Because there was not a consistent optimum based on T_{50}, Durrant used mean radicle length of germinating seeds as the primary index to determine optimum priming duration.

Total emergence did not differ between experiments 1 and 2 and averaged 87%. In each experiment a significant quadratic relationship with treatment duration was detected. Contrasts testing linear and cubic trends in total emergence were not significant in either experiment. A second-order polynomial fitted to the combined data from both experiments showed that both first and second order terms for duration of treatment were significant (Table 1b) and that total emergence declined with treatment durations in excess of 3 days (Fig. 1b). Because regression can't account for variability between blocks, this polynomial explained only 40% of total variability. However, the analysis of variance model accounted for 64% of total variability (data not shown), and confirmed that mean total emergence after 4 and 5 days of treatment was significantly lower than the mean for 3 days of treatment ($P = 0.06$ and $P = 0.008$, respectively).

Treating WS-88 sugarbeet seed for 3 days with 300 g/L PEG was optimal for obtaining both maximum stand and enhanced emergence rate, and insured a broad margin of safety against sprouting during priming. If T_{50} values had been used as a sole

Table 1. Parametric statistics for regression of days of PEG treatment on a) time to 50% of total emergence (T_{50}) and b) total emergence in experiments 1 and 2.

CV = 7.8%
r^2 = 0.64

a) $T_{50} = 5.8 - 0.6(D) + 0.2(D*E)$
where: D = days of PEG treatment
E = experiment

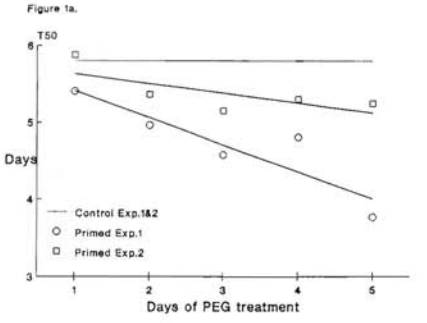
Parameter	Estimate	Std. Error	Pr> |T|
Intercept	5.8	0.1	0.0001
Days of Trt (D)	-0.6	0.06	0.0001
Interaction (D*E)	0.2	0.03	0.0001

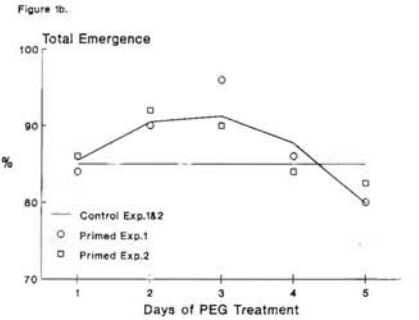
CV = 11.0%
r^2 = 0.16

b) Total = $72.00 + 16.06(D) - 3.14 (D)^2$
where: D = days of PEG treatment
$(D)^2$ = (days of PEG treatment)^2

Parameter	Estimate	Std. Error	Pr> |T|
Intercept	76.2	6.5	0.0001
Days of Trt (D)	11.5	5.0	0.03
(Days of Trt)^2 [(D) ^{2}]	-2.1	0.8	0.01

Figure 1. Regression of duration of 300 g/L PEG treatment of sugarbeet seeds on a) time to 50% of total emergence and b) total emergence in two greenhouse experiments. Plotted points are means of five replicates. The mean value for untreated seeds in the two experiments is presented for comparison.





predictor of optimal priming treatment, 5 days would have been selected as the optimal treatment duration. At this duration, total emergence would have been 11% below that of the 3-day treatment. Thus, it is important to use both speed and total emergence as indices when selecting an optimal priming duration from an emergence test. Total emergence may be more closely related to seedling vigor than total germination. Therefore, radicle length may be a better index than total germination for determining optimal priming duration when a germination test is used.

Storage Experiments 3 and 4.

In the absence of storage effects, seedlings from primed sugarbeet seeds emerged a day earlier than those from unprimed seeds (Table 2a). Total emergence was not affected by priming and averaged 90%. Seedlings emerged faster in experiment 4 but had lower final emergence than seedlings in experiment 3 (Table 2b). These differences between experiments may be due to the effects of seedlots, or to temperature differences in the greenhouse during the emergence tests or both. The interaction of priming effect with experiment was not significant.

In both experiments T_{50} was linearly related to weeks of storage but unaffected by storage temperatures. Linear contrasts for quadratic and cubic trends in T_{50} of the combined data were not significant, nor was the interaction of experiment with storage time. The linear regression model of the combined data contained experiments and weeks of storage as significant elements (Table 3a). Regression of T_{50} on weeks of storage showed an increase in T_{50} of 0.05 days for each week of storage (Fig. 2a). In both experiments primed seed emerged faster than untreated seed regardless of storage time.

Storage temperatures had no effect on total emergence in either experiment 3 or 4 (data not shown). A significant quadratic trend was noted in response to weeks of storage in both experiments, but the experiment by storage time interaction was not significant. Linear and cubic trends in the data were not detected.

A second order polynomial was fitted to the combined data. The resulting first and second order parameter estimates for storage effects were highly significant. However, regression explained only 28% of the total variability (Table 3b), and the range of values predicted by regression was small (90-96%) (Fig. 2b). Apparently, this quadratic relationship is of little importance in determining final emergence.

The results of these experiments together with the work of Durrant et al. (1983a, 1983b) and Khan et al. (1983) show that sugarbeet seeds can be primed at temperatures from 15 to 24°C.

Table 2. Effect of priming (a) and experiment (b) on total emergence and T_{50} of sugarbeet seed (in two greenhouse tests). Primed seeds were planted immediately after drying back to original seed moisture.

a)

Treatment	Total Emergence	T_{50}
	%	-days-
None(control)	91.3	4.5
Primed	88.8	3.5
LSD ($P = 0.05$)	N.S.	0.4

b)

Treatment	Total Emergence	T_{50}
	%	-days-
3	96.3	4.2
4	83.8	3.8
LSD ($P = 0.05$)	10.9	0.3

Table 3. Parametric statistics for regression of days of PEG treatment on a) time to 50% of total emergence (T_{50}) and b) total emergence in experiments 3 and 4.

CV = 9.4%
$r^2 = 0.64$

a) $T_{50} = 6.6 - 0.9(E) + 0.05\ (W)$
where: E = experiment
W = weeks of storage

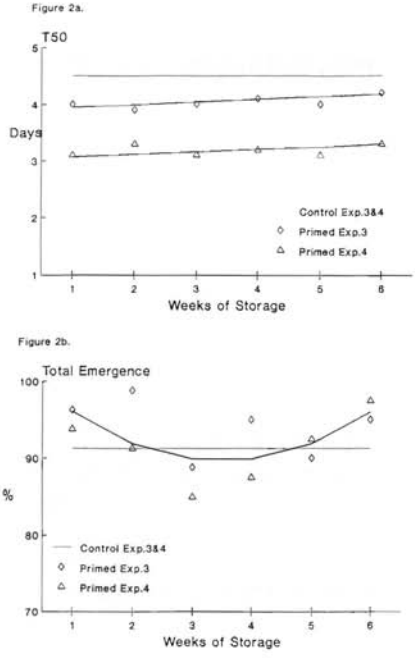
Parameter	Estimate	Std. Error	Pr>|T|
Intercept	6.6	0.2	0.0001
Experiment (E)	-0.9	0.07	0.0001
Weeks of storage(W)	0.05	0.02	0.02

CV = 9.6%
$r^2 = 0.08$

b) $\text{Total} = 102.3 - 7.2(W) + 1.0(W)^2$
where: W = weeks of storage
$(W)^2$ = (weeks of storage)^2

Parameter	Estimate	Std. Error	Pr>|T|
Intercept	102.3	4.0	0.0001
Weeks of storage (W)	-7.2	2.6	0.007
(Weeks of storage)^2 [$(W)^2$]	1.0	0.4	0.006

Figure 2. Regression of weeks of storage on a) time to 50% of total emergence, and b) total emergence of primed sugarbeet seed. Plotted points are means of 8 observations. The mean value for untreated seeds in the two experiments is presented for comparison.



Priming solutions with water potentials less than -1.5 MPa will obviate the problem of sprouting during treatment. Optimal treatment durations should be determined using either radicle length in the case of germination tests, or total emergence in pot or field emergence tests. Primed sugarbeet seed may be stored in open containers for up to 6 weeks with little loss of priming effects.

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LITERATURE CITED

Alvarado, A.D., and K.J. Bradford. 1988. Priming and storage of tomato seeds. I. Effects of storage temperature on germination rate and viability. Seed Sci. Technol. 16:601-612.

Baker, E.H., and C.M. Rush. 1989. Preliminary studies on seed priming of sugarbeet. J. Sugar Beet Research 26(1):A2.

Bradford, K.J. 1986. Priming to improve germination under stress conditions. HortScience 21(5): 1105-1112.

Dearman, J., P.A. Brocklehurst, and R.L.K. Drew. 1986. Effects of osmotic priming and ageing on onion seed germination. Ann. Appl. Biol. 108:639-648.

Durrant, M.J., P.A. Payne, and J.S. McLaren. 1983a. The use of water and some inorganic salt solutions to advance sugarbeet seed. I. Laboratory studies. Ann. Appl. Biol. 103:507-515.

Durrant, M.J., P.A. Payne, and J.S. McLaren. 1983b. The use of water and some inorganic salt solutions to advance sugar beet seed: II. Experiments under controlled and field conditions. Ann. Appl. Biol. 103:517-526.

Hardegree, S.P., and W.E. Emmerich. 1990. Effect of polyethylene glycol exclusion on the water potential of solution-saturated filter paper. Plant Physiol. 92:462-466.

Heydecker, W. 1977. Stress and seed germination. Pages 240-282. *In* A.A. Khan (ed.). The Physiology and Biochemistry of Seed Dormancy and Germination. Elsevier/North-Holland, Amsterdam.

Khan, A.A., N.H. Peck, A.G. Taylor, and C. Samimy. 1983. Osmoconditioning of beet seeds to improve emergence and yield in cold soil. Agron. J. 75:788-794.

Longden, P.C., and M.G. Johnson. 1974. Effect of water content and storage temperature on monogerm sugarbeet seed performance. Seed Sci. and Technol. 2:411-420.

Michel, B.E. 1983. Evaluation of the water potentials of polyethylene glycol 8000 both in the absence and presence of other solutes. Plant Physiol. 72:66-70.

Sale, P.J.M., and D.J. Harrison. 1964. Seedling emergence as affected by soil capping. J. Hort. Sci. 39:147-161.