Stand Establishment of Sugar Beet Seedlings in Pathogen-Infested Soils as Influenced by Cultivar and Seed-Priming Technique

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ABSTRACT

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A greenhouse study was conducted to determine whether selected sugar beet (*Beta vulgaris*) cultivars responded differently to various seed-priming techniques. Priming techniques included osmopriming with −1.5 MPa NaCl or −1.2 MPa polyethylene glycol (PEG 8000) and solid matrix priming with water and a hydrous silicate clay mineral as the solid substrate. Washed and nontreated seed were used as controls. Treated seed of cultivars Ach146, Ach177, HH42, and Tx9 was planted in a silt loam–peat soil mix artificially infested with *Aphanomyces cochlioides* or *Pythium ultimum*, or in noninfested soil. Seedling emergence and damping-off were recorded daily. Although varying in degree, all cultivars responded similarly to the different seed treatments. There was typically no seed treatment × cultivar interaction with any of the recorded variables at any time. All priming treatments increased the rate and uniformity of seedling emergence and also reduced the incidence of preemergence damping-off in soils infested with *P. ultimum*. There was a small but significant positive correlation between T_{50} (the weighted mean time for emergence of all seedlings) and preemergence damping-off ($R^2 = .23$, $P \leq 0.05$). As T_{50} increased (slower emergence), preemergence damping-off increased. *P. ultimum* caused both preemergence and postemergence damping-off; however, *A. cochlioides* caused only postemergence damping-off. Although priming treatments reduced preemergence damping-off, no treatment significantly reduced postemergence damping-off.

Each year approximately 17,000 ha of sugar beet (*Beta vulgaris* L.) are planted in the Texas Panhandle. Although environmental conditions are favorable for sugar beet production, the silt loam soils are prone to form surface crust, which results in stand establishment problems. Additionally, seedling disease caused by *Pythium ultimum* Trow (3) and *Aphanomyces cochlioides* Drechs. (29) contributes to the difficulty of establishing an adequate stand. Any treatment that could speed seedling emergence or reduce damping-off would be of great value to sugar beet producers.

For years researchers have evaluated the effects of seed soaking and priming on germination and emergence variables. Van Doren and Henry (38) found that incubating sugar beet seed at 15 C for 6 days in blotter paper moistened with a solution of 1.5% KNO_3 plus 1.5% K_3PO_4 stimulated germination, especially under adverse temperature and moisture conditions. Durrant et al (11) evaluated a variety of inorganic salt solutions in addition to distilled water for effects on germination rate. They found that all treatments resulted in faster germination rates, but that osmotic solutions were preferable, because "inadvertent germination was less likely." They also made a distinction between seed priming and seed "advancement": the latter referred to increasing the rapidity of seed germination but not synchronicity, whereas true seed priming increased both.

In addition to using inorganic salts as osmotica in seed-priming research, numerous workers have evaluated polyethylene glycol (PEG) solutions (1,6,17, 21,24). In general, PEG has been as effective as inorganic salts in speeding germination; however, because of the viscosity of PEG solutions, adequate aeration has been problematic (1,5). Both PEG and inorganic salts have consistently improved germination rate and stand establishment compared to only soaking seed in distilled water (11,12,30). Priming with PEG or inorganic salts has also given the added benefit of reducing incidence of seedling damping-off in soils infested with *Pythium ultimum* (26,27,30,35).

In recent years, a new method of seed priming, termed solid matrix priming (SMP), has been developed by John Eastin (U.S. patent 4,912,874) (13,36,37). SMP differs from traditional priming in that a solid carrier is used to regulate water availability to seeds. Depending on the choice of solid carrier, the water potential is regulated by osmotic or matric components, or both (13,15). SMP has been shown to be as good or better than traditional "osmopriming" with respect to speeding seedling germination and reducing the incidence of Pythium damping-off (15,16,30). However, because SMP is relatively new, it was not known whether the procedure would require modification for every cultivar, or whether seedling disease caused by pathogens other than *P. ultimum* would be affected. These same questions also apply to osmopriming with PEG or inorganic salts. Therefore, a study was conducted to determine if selected sugar beet cultivars varied in their response to priming methods with regard to stand establishment and susceptibility to *P. ultimum* or *A. cochlioides*. Preliminary reports have been published (3,4).

MATERIALS AND METHODS

Cultivars and seed treatments. Four commercially available sugar beet culti-

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vars from three companies were used: Tx9 (Hilleshog Mono-hy, Inc., Longmont, CO); HH42 (Holly Sugar Corp., Sheridan, WY); and Ach146 and Ach177 (American Crystal Sugar Co., Moorhead, MN). None has specific genetic resistance to *P. ultimum*, and only the cultivar Ach146 has tolerance to *A. cochlioides*. Seed from all sources was processed commercially and was identical to that available to producers, except that none had received chemical seed treatments.

Seed of each cultivar was osmoprimed using NaCl and PEG 8000 as osmotica, solid matrix-primed using distilled water and a dry hydrous silicate clay as the solid matrix, washed only with distilled water, and nontreated. Osmoprimed seed was incubated in −1.5 MPa of NaCl or −1.2 MPa of PEG 8000 for 6 days at 15 C. SMP was achieved by mixing 22.7 g of seed with 22.7 g of solid matrix and 22 ml of H_2O, incubating it for 2 days at 15 C, and drying it for 3 days. The washed treatment entailed washing seed in distilled H_2O six times, 30 min each, on a rotary shaker at 15 C. More specific detail of techniques used for the two osmopriming treatments (26,27) and the SMP treatment (30) has been reported.

Soil mix and inoculum preparation. An unsterile clay loam soil was mixed with peat (5:2, v/v) and used in all studies. For pathogen infested soil treatments, *P. ultimum* and *A. cochlioides* were grown in vitro and added to the soil mix at desired rates. *A. cochlioides* was grown in liquid culture (30). After approximately 1 mo, mycelial mats containing mature oospores were comminuted in a blender for 2–3 min. Oospores were counted with a hemacytometer, added to an unsterile silt loam, and allowed to air-dry. This stock was then added to the soil mix to give an oospore density of approximately 300 oospores per gram of soil mix. *P. ultimum* was grown in an oatmeal broth–vermiculite mixture (30) and added to the soil mix at a rate of 2.5% (w/w). Soils infested with *A. cochlioides* or *P. ultimum* were mixed thoroughly in a cement mixer prior to use.

Seed treatment effects on seedling disease and cultivar stand establishment. Studies were conducted in a greenhouse with no supplemental lighting at the Texas Agricultural Experiment Station, Bushland. Plastic flats (53 × 28 × 5 cm) were filled with noninfested soil mix or mix infested with *A. cochlioides* or *P. ultimum*, and 15 seeds per replication of each cultivar-seed treatment combination were planted. Three flats of each soil treatment were required to plant one complete replication of the 20 seed treatment-cultivar combinations. Treatments were replicated six times, and flats were arranged in a randomized complete block design with nine flats, three of each soil treatment per block.

Immediately after planting, all flats were irrigated, and no additional water was added until after seedling emergence. Once seedlings emerged, flats were watered frequently to promote disease development. Stand counts began 3 days after planting and continued for 15 days. Each day, the number of newly emerged seedlings or those that showed postemergence damping-off was recorded. In soils infested with *A. cochlioides*, seedlings exhibiting typical black root symptoms (28) were counted as having damping-off. Preemergence damping-off was considered to be the difference between seed planted and the number of seedlings emerged after 8 days. The experiment was conducted twice, once in early June, and again in August.

Data analysis. Emergence and disease data were analyzed separately for each of the three soil treatments. All data were subjected to ANOVA for a split plot, with cultivars the main treatment and seed treatment the split. Treatment means were separated using Duncan's multiple range test. Mean emergence period, or T_{50}, the weighted mean time required for emergence of all seedlings (2,19), was determined for all seed treatments and cultivar combinations in noninfested soils using the formula $T_{50} = \Sigma Ti\ Ni/\Sigma Ni$, where Ni is the number of newly emerged seedlings at time Ti. The same formula has previously been designated as mean emergence rate, MER (30), and mean rate of emergence, MRE (27). However, the use of rate in place of time or period has caused considerable confusion. Regression analysis was used to determine the relation between T_{50} and preemergence damping-off in *P. ultimum*-infested soil. Synchronicity of emergence was evaluated by determining the percentage of the maximum stand that had emerged 3, 4, and 5 days after planting. Maximum stand was considered to be the total number of seedlings that had emerged by day 8.

RESULTS

Analysis of results from the first and second experiments indicated that the two were significantly different. However, the difference was more quantitative than qualitative. Temperatures during the first experiment conducted in June were cooler, especially the first 4 days after planting, than those in August, when the second experiment was conducted. As a result, stand counts inclusive of all cultivar and seed treatments were significantly higher in each soil treatment in experiment 2 (Table 1). Also, preemergence damping-off caused by *P. ultimum*, generally a cool temperature pathogen (18), was more severe in experiment 1, as evidenced by the 3- and 8-day stand counts.

Daily watering during experiment 1 was conducive for disease caused by both pathogens, but the wet soils were especially conducive for *A. cochlioides*, which is dependent on near-saturated soil conditions for zoosporic movement (10,20,28). During experiment 2, reduced irrigation frequency, once every 2–3 days, resulted in significantly greater final stands in soils infested with *A. cochlioides*. Despite these quantitative differences, there was seldom any seed treatment × cultivar interaction for any measurement in either experiment. Although the degree of response to particular treatments varied between repeated experiments, overall trends and treatment effects were similar. However, because the two experiments were significantly different, and there were some experiment × treatment interactions, results of repeated experiments are shown separately unless otherwise indicated.

Influence of soil treatments on type and extent of disease development. Conditions were favorable for disease

Table 1. Stand establishment of sugar beet seedlings in two greenhouse experiments[w]

	Seedling emergence (%)		
	Soil treatment[x]		
Emergence counts	*Aphanomyces*	Noninfested	*Pythium*
3-Day emergence			
Experiment 1	19 a[y]	19 a	7 a
Experiment 2	26 b	25 b	21 b
8-Day emergence			
Experiment 1	85 a	79 a	37 a
Experiment 2	87 b	87 b	60 b
Final stand[z]			
Experiment 1	7 a	79 a	25 a
Experiment 2	42 b	87 b	31 b

[w] The first greenhouse study (experiment 1) was conducted June 1–16 and was repeated August 4–19 (experiment 2).

[x] *Aphanomyces cochlioides* and *Pythium ultimum* were added to an unsterile silt loam soil mix at approximately 300 oospores per gram and 2.5% w/w, respectively.

[y] Values represent the mean of four cultivars and five seed treatments, with six replications of each cultivar-seed treatment combination. Means followed by the same letter are not significantly different according to Duncan's multiple range test ($P = 0.05$).

[z] Final stand 15 days after emergence was based on percentage of total seed planted, not number of plants emerged.

Table 2. Effect of seed treatment on sugar beet seedling emergence, damping-off, and final stand in soil infested with *Aphanomyces cochlioides*

	Seedling emergence (%)[x]				Postemergence damping-off (%)		Final stand (%)[z]	
	Day 3		Day 8					
Seed treatment[w]	Exp. 1[y]	Exp. 2	Exp. 1	Exp. 2	Exp. 1	Exp. 2	Exp. 1	Exp. 2
SMP	52 a	67 a	89 ab	91 ab	91 a	52 a	7 a	43 a
NaCl	19 b	34 b	86 bc	82 d	92 a	53 a	6 a	38 a
PEG	11 bc	21 c	78 d	83 cd	87 a	49 a	9 a	42 a
Washed	10 bc	9 d	92 a	94 a	92 a	54 a	6 a	42 a
Control	2 c	1 e	80 cd	87 bc	90 a	47 a	6 a	45 a

[w] Osmoprimed seed was incubated in −1.5 MPa NaCl or −1.2 MPa polyethylene glycol (PEG 8000) for 6 days at 15 C. Solid matrix priming (SMP) was achieved by mixing 22.7 g of seed with 22.7 g of solid matrix and 22 ml of H_2O, incubating it for 2 days at 15 C, and then drying it for 3 days. The washed treatment entailed washing seed in distilled H_2O six times, 30 min each, on a rotary shaker at 15 C.

[x] There was no seed treatment × cultivar interaction, and values in each column represent means for each seed treatment, inclusive of all cultivars. Means followed by the same letter are not significantly different according to Duncan's multiple range test ($P = 0.05$).

[y] The first greenhouse study, experiment 1 (Exp. 1), was conducted June 1–16 and was repeated August 4–19 (Exp. 2).

[z] Final stand 15 days after emergence was based on percentage of total seed planted, not number of plants emerged.

Table 3. Effects of seed treatment on sugar beet seedling emergence, damping-off, and final stand in soil infested with *Pythium ultimum*

	Seedling emergence (%)[x]				Preemergence damping-off		Postemergence damping-off		Final stand (%)[z]	
	Day 3		Day 8							
Seed treatment[w]	Exp. 1[y]	Exp. 2	Exp. 1	Exp. 2	Exp. 1	Exp. 2	Exp. 1	Exp. 2	Exp. 1	Exp. 2
SMP	25 a	50 a	61 a	71 a	39 a	29 a	26 a	49 a	44 a	36 a
NaCl	5 b	27 b	52 a	66 a	47 a	34 a	35 a	50 a	36 a	34 a
PEG	4 b	23 b	39 b	67 a	61 b	33 a	37 a	42 a	24 b	40 a
Washed	2 b	4 c	18 c	47 b	82 c	53 b	39 a	55 a	10 c	20 b
Control	1 b	1 c	16 c	47 b	84 c	53 b	24 a	43 a	12 c	25 b

[w] Osmoprimed seed was incubated in −1.5 MPa NaCl or −1.2 MPa polyethylene glycol (PEG 8000) for 6 days at 15 C. Solid matrix priming (SMP) was achieved by mixing 22.7 g of seed with 22.7 g of solid matrix and 22 ml of H_2O, incubating it for 2 days at 15 C, and then drying it for 3 days. The washed treatment entailed washing seed in distilled H_2O six times, 30 min each, on a rotary shaker at 15 C.

[x] Values in each column represent means for each seed treatment inclusive of four cultivars. Means followed by the same letter are not significantly different according to Duncan's multiple range test ($P = 0.05$).

[y] The first greenhouse study, experiment 1 (Exp. 1), was conducted June 1–16 and was repeated August 4–19 (Exp. 2).

[z] Final stand 15 days after planting was based on seed planted, not number of plants emerged.

Table 4. Seed treatment effects on sugar beet seedling emergence in noninfested soil

	Seedling emergence (%)[x]				Final stand[z]	
	Day 3		Day 8			
Seed treatment[w]	Exp. 1[y]	Exp. 2	Exp. 1	Exp. 2	Exp. 1	Exp. 2
SMP	47 a	66 a	86 a	81 ab	88 a	85 a
NaCl	22 b	28 b	78 b	83 b	86 a	85 a
PEG	4 c	24 b	74 bc	86 ab	78 b	86 a
Washed	15 b	8 c	89 a	91 a	74 bc	91 b
Control	4 c	1 d	67 c	86 ab	69 c	88 ab

[w] Osmoprimed seed was incubated in −1.5 MPa NaCl or −1.2 MPa polyethylene glycol (PEG 8000) for 6 days at 15 C. Solid matrix priming (SMP) was achieved by mixing 22.7 g of seed with 22.7 g of solid matrix and 22 ml of H_2O, incubating it for 2 days at 15 C, and then drying it for 3 days. The washed treatment entailed washing seed in distilled H_2O six times, 30 min each, on a rotary shaker at 15 C.

[x] There was no seed treatment × cultivar interaction, and values in each column represent means for each seed treatment, inclusive of all cultivars. Means followed by the same letter are not significantly different according to Duncan's multiple range test ($P = 0.05$).

[y] The first greenhouse study, experiment 1 (Exp. 1), was conducted June 1–16 and was repeated August 4–19 (Exp. 2).

[z] Final stand 15 days after emergence was based on percentage of total seed planted, not number of plants emerged.

development during both experiments, but the type of disease caused by the two pathogens was different. *P. ultimum* predominantly caused preemergence damping-off, whereas *A. cochlioides* caused only postemergence damping-off. Stand establishment at 3 and 8 days after planting was less in soils infested with *P. ultimum* than in *Aphanomyces*-infested and noninfested soils. In contrast, stands in soils infested with *A. cochlioides* were equal to or greater than those in noninfested soils at days 3 and 8, regardless of seed treatment. There was no preemergence damping-off in soils infested with *A. cochlioides*, but there was extensive postemergence damping-off.

Cultivar and seed treatment effects on stand establishment and disease incidence. Cultivars and seed treatments significantly affected stand establishment in the different soil treatments. However, there was typically no cultivar × seed treatment interaction, so data are expressed as seed treatment effect inclusive of all cultivars (Tables 2, 3, and 4).

All priming treatments increased 3-day stand establishment compared to the nontreated control, and differences were usually significant. By day 8, there were fewer differences. In soils infested with *A. cochlioides* (Table 2), the only priming treatment that gave a significantly better stand than the nontreated control was SMP, and this occurred only in the first experiment. However, at day 8 and final stand, in soil infested with *P. ultimum* (Table 3) all three priming treatments resulted in significantly better stands than the nontreated control. The better final stands from the priming treatments in *P. ultimum*-infested soils were a result of reduced preemergence damping-off. No treatment or cultivar reduced the incidence of postemergence damping-off caused by either pathogen. Even Ach146, which has partial resistance to Aphanomyces seedling disease, had only 25% stand survival after 15 days, no better than any other cultivar (*data not shown*).

Seed treatment effects on rate and uniformity of seedling emergence. The effects of seed priming on T_{50} was similar with all varieties and seed treatments (Table 5), and typically there was no seed treatment × cultivar interaction. All cultivars responded similarly to given seed treatments, and significant differences in T_{50} among the cultivars within a given treatment were minimal. Priming seed significantly reduced T_{50}, and differences between priming techniques were usually, but not always, significant. In general, however, the SMP treatment had

the fastest rate of emergence. When seed treatment effects on T_{50}, inclusive of all cultivars, were evaluated, all priming treatments were significantly different from the nontreated control, and SMP was significantly better than all other treatments.

In addition to affecting the rate of emergence, seed priming also affected uniformity. Cultivars responded similarly to individual seed treatments (Fig. 1), and there was no treatment × cultivar interaction. Stand counts were first taken 3 days after planting, and at that time emergence from SMP-treated cultivars was already 60–80% of the maximum stand achieved 8 days after planting. At the same time, emergence from nontreated seed was less than 10% of 8-day maximum emergence for all cultivars. Even by day 5, nontreated Tx9 and HH42 had not reached the level of emergence the same cultivars treated with SMP had achieved on day 3.

Seed treatments affected the rate and uniformity of seedling emergence, and there was also a small but significant relationship between T_{50} and preemergence damping-off in soils infested with *P. ultimum*. When all data was used in regression analysis, the coefficient of determination was $R^2 = .23$ ($P \leq 0.05$). In general, as T_{50} decreased, preemergence damping-off also decreased.

DISCUSSION

The concept of priming sugar beet seed to improve earliness and uniformity of seedling emergence has generated considerable interest within the seed industry. However, before acceptance, a treatment must exhibit a broad degree of application and effectiveness. A process requiring modification for every cultivar or seed lot would be unacceptable.

Numerous researchers have shown sugar beets to be amenable to preconditioning with water (21–25) and to priming with traditional osmotic techniques (26,27,30) or the more recent solid matrix technique (30). However, few have intentionally evaluated different techniques and cultivars with the objective of identifying potential cultivar × seed treatment interactions.

Murray and Gallian (21,22) and Murray et al (23–25) showed preconditioning sugar beet seed with water or osmopriming with PEG was generally effective in increasing the rate of seedling emergence. Considerable variation in these results was observed, however, especially with PEG treatments. They concluded osmopriming with PEG held promise, but each cultivar, and possibly each seed lot, would require pretesting (24,25). Other researchers have also reported difficulties or inconsistencies when osmopriming with PEG (1,30,36). In the present study, PEG was effective in speeding emergence and reducing preemergence damping-off in soils infested with *P. ultimum*. Still, even though similar results were obtained with all cultivars, it was the most variable of all treatments. The variability experienced when osmopriming with PEG, along with its inconsistent performance and expense, will most likely preclude its widespread acceptance or use.

Variability was common in the present study between repeated experiments, and among cultivars, seed treatments, and soil treatments. However, the consistency of results was encouraging. General trends among cultivars and seed treatments were constant despite variability in the degree of response. The fact that there was typically no seed treatment × cultivar interaction suggests that seed priming of sugar beet on a commercial scale is feasible. SMP and osmopriming with NaCl were both effective in increasing earliness and uniformity of emergence. Within a given seed treatment, cultivars varied in degree of response, but all performed significantly better than nontreated seed. Variation in the degree of cultivar response to different seed treatments suggests that improvement with selected cultivar-seed treatment combinations is possible. However, finding that treatment modification is not required with each cultivar in order to obtain significant improvement over nontreated seed was encouraging.

A discouraging and consistent aspect

Table 5. Mean emergence period[x] of sugar beet cultivars in noninfested soil as affected by selected seed treatments

	Seed treatments[y]					
	Experiment 1[z]			Experiment 2		
Cultivars	Control	NaCl	SMP	Control	NaCl	SMP
Ach146	5.4 a A	5.0 a B	4.5 a C	4.8 a A	3.7 a B	3.3 a C
Ach177	5.5 a A	4.3 a B	3.8 ab B	4.7 a A	3.7 a B	3.4 a C
HH42	5.9 a A	4.5 a B	4.5 a B	5.0 a A	4.0 a B	3.3 a C
Tx9	5.6 a A	4.7 a B	3.6 b C	4.7 a A	4.2 a B	3.4 a C
Treatment mean	5.6 A	4.6 B	4.1 C	4.8 A	3.9 B	3.6 C

[x] Mean emergence period (T_{50}), the weighted mean time required for emergence of all seedlings, was determined as $T_{50} = \Sigma\ Ti\ Ni / \Sigma\ Ni$, where Ni is the number of newly emerged seedlings at time Ti. Means for each experiment within a column followed by the same lowercase letter or in a row followed by the same uppercase letter are not significantly different according to Duncan's multiple range test ($P = 0.05$).

[y] NaCl-treated seed was incubated in −1.5 MPa NaCl for 6 days at 15 C. Solid matrix priming (SMP) was achieved by mixing 22.7 g of seed with 22.7 g of solid matrix and 22 ml of H_2O, incubating it for 2 days at 15 C, and then drying it for 3 days.

[z] The first greenhouse study (experiment 1) was conducted June 1–16 and was repeated August 4–19 (experiment 2).

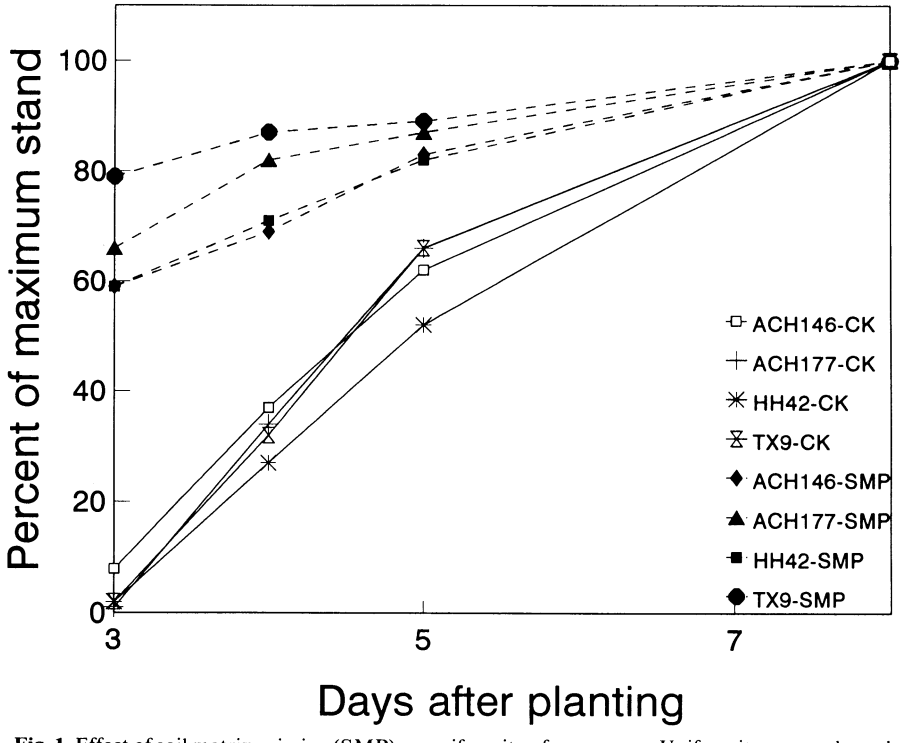

Fig. 1. Effect of soil matrix priming (SMP) on uniformity of emergence. Uniformity was evaluated by determining the percentage of the maximum stand (total seedlings emerged by day 8) that had emerged 3, 4, or 5 days after planting. Every SMP-treated cultivar had a significantly better stand than the same nontreated cultivar at every count.

of this study was the failure of any treatment to reduce seedling disease in soils infested with *A. cochlioides*. Final stands with all seed treatment-cultivar combinations were drastically reduced compared to those in noninfested soils. There was a highly significant experiment effect on Aphanomyces seedling disease, but even though the degree of response differed between experiments, there was no seed treatment or cultivar effect on final stands.

The large amount of postemergence damping-off in soils infested with *A. cochlioides* during the first experiment was probably due to excessive watering. The intention was to create an optimum environment for disease development, but conditions were so favorable that treatment effects were possibly masked. However, in experiment 2, where reduced watering resulted in a sixfold increase in final stand (Table 1), there was still no treatment effect on disease incidence (Table 2).

Although discouraging, the lack of any treatment effect on Aphanomyces seedling disease was not surprising. Nor was it surprising that preemergence damping off caused by *P. ultimum* was significantly reduced by all priming treatments (Table 3). Numerous researchers have reported that disease caused by *P. ultimum* can be reduced by osmopriming with NaCl and PEG (26,27,30) or by solid matrix priming (15,16,30). However, the type of disease caused by *P. ultimum* is quite different from that caused by *A. cochlioides*. Both pathogens are most destructive in moist soils (7,14,33,34), but *A. cochlioides*, as other zoosporic plant pathogens, requires nearly saturated soils for infection (9,10,20). Inoculum density (28,31,32) and soil temperature (28) are also important variables that can affect Aphanomyces seedling disease, but if adequate soil water is not available, disease will not occur, regardless of other parameters (7).

When adequate soil moisture is available, infection by *A. cochlioides* can occur rapidly. MacWithey (20) reported infection of sugar beet seedlings by *A. cochlioides* zoospores with as little as 2 hr of exposure. Disease severity was dependent on zoospore number and length of exposure (20). Although zoospore infection can occur rapidly, in the present study there was no preemergence damping-off in soils infested with *A. cochlioides*. This is consistent with previous reports (28), and with observations by the author of disease occurrence in the field. Unlike *P. ultimum*, which can infect seed within hours after planting (33,34), *A. cochlioides* does not infect the seed (28), and disease typically does not appear until seedlings are well established (8,28). Since infection by *P. ultimum* is influenced by seed exudates during germination (14,34), it is not surprising that priming treatments affect the incidence of preemergence, but not postemergence, damping-off. These results support the hypothesis that seed priming reduces preemergence damping-off by affecting the quality or quantity of seed exudates during germination (26) rather than affecting indigenous bacterial populations on the seed (15,26) or merely outgrowing the pathogen (18). The low coefficient of determination ($R^2 = .23$), obtained when evaluating the relation between T_{50} and preemergence damping-off, also indicates that factors other than "outgrowing the pathogen" are at work.

Seed priming is a technology with potential for use by the sugar beet seed industry. Osmotic and solid matrix priming improved the earliness and uniformity of seedling emergence and reduced the incidence of preemergence damping-off caused by *P. ultimum*. All cultivars responded in like manner to individual priming treatments, but the degree of response varied. Although results are promising, the true value and potential of seed priming technology must be determined from extensive field testing.

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