Matric Priming of Kentucky Bluegrass and Tall Fescue Seeds Benefits Seedling Emergence

Wallace G. Pill, John J. Frett, and Ian H. Williams

Department of Plant and Soil Sciences, University of Delaware, Newark, DE 19717-1303

Additional index words. *Festuca arundinacea*, *Poa pratensis*, turfgrass

Abstract. Matrically priming seeds of common Kentucky bluegrass (*Poa pratensis* L.) and 'SR8300' tall fescue (*Festuca arundinacea* Schreb.) in fine, exfoliated vermiculite (−1.5 MPa, 20 °C, 4 days) increased subsequent germination rate but did not increase germination percentage or synchrony. The lowest seed : vermiculite ratio (dry weight basis) to provide full priming benefit for seeds of Kentucky bluegrass and tall fescue was 1:10 and 1:20, respectively. Storing Kentucky bluegrass seeds primed in 1:10 (seed:vermiculite) in moist vermiculite for 10 days at either 5 or 20 °C did not reduce germination rate in comparison to primed seeds that were not stored. Primed tall fescue seeds could be stored in moist vermiculite (1:20, seed:vermiculite) for up to 10 days at 5 °C with no loss of priming benefit, but storage for only 2 days at 20 °C resulted in germination. Primed seeds of Kentucky bluegrass (stored for 0 or 10 days at 5 or 20 °C) or tall fescue (stored 0 or 10 days at 5 °C or 2 days at 20 °C) resulted in more rapid germination and seedling emergence, and greater seedling shoot fresh and dry masses than was the case for nonprimed seeds.

Priming is a preplant, low water potential seed treatment that permits partial seed hydration; pregerminative metabolic activities proceed but germination is prevented (Pill, 1995). Priming can increase seed vigor, especially under adverse conditions such as low temperature (Pill and Finch-Savage, 1988) and reduced water availability (Frett and Pill, 1989). Matric priming involves exposing seeds to solids containing limited amounts of water or aqueous solution. [See reviews by Khan (1992), Parera and Cantliffe (1994), and Pill (1994)]. The sowing of primed turfgrass seeds can shorten the establishment period; this may be advantageous under heavy traffic conditions as found in athletic fields (Dudeck and Peacock, 1986), in cold seedbeds, when cosmetic repairs are needed urgently, when competition from weeds is expected, or when a slowly germinating component of a seed mixture is expensive or in low proportion (Lush and Birkenhead, 1987).

Priming of seeds of four fescue species in fine exfoliated vermiculite (−1.5 MPa, 20 °C, 4 d) resulted in superior postpriming seed germination than did priming 1) in polyethylene glycol or sodium nitrate, 2) at higher water potentials, 3) at lower temperatures, or 4) for longer durations (Frett and Pill, 1995). Matric

priming of Kentucky bluegrass seeds resulted in superior germination than did osmotic priming (Pill and Korengel, 1997). Priming increased the germination rate at 15, 25, or 35 °C, and increased both germination synchrony and percentage at high temperature and reduced water availability. In further work (Pill and Korengel, 1997), matric priming (−1.5 MPa, 20 °C, 4 d) of Kentucky bluegrass seeds resulted in faster germination than osmotic priming. Matric priming advanced seedling emergence, increased percentage of emergence, and increased seedling shoot dry masses relative to no priming.

Rather than separate the primed seeds from the vermiculite, the mixture can be sown. The vermiculite is sufficiently dry at −1.5 MPa to permit easy dispersal of the seed-vermiculite mixture without drying. The primed seeds may have to be stored if sowing is delayed.

Since we know of no reports of the effects on germination or seedling emergence of either seed : vermiculite ratio during priming, or the effects of postpriming storage of seeds in moist vermiculite, the present studies were undertaken using seeds of Kentucky bluegrass and tall fescue.

Materials and Methods

Experiment 1. Seed to vermiculite ratio. Single seedlots of common Kentucky bluegrass and 'SR8300' tall fescue, purchased from commercial sources, were mixed with fine exfoliated vermiculite (Grade 5; W.R. Grace, Cambridge, Mass.) at seed : vermiculite mass ratios of 1:10, 1:20, 1:30, or 1:40. Fifty seeds of Kentucky Bluegrass (16.7 mg) and tall fescue (93.0 mg) were placed in 25- and 33-mL plastic souffle cups (Solo Cup Co., Urbana, Ill.), respectively, and the appropriate amounts of vermiculite added. The −1.5 MPa

matric potential was achieved by adding 50% (m/m) water to vermiculite (Khan et al., 1990, 1992). The seeds, vermiculite, and water were mixed thoroughly by stirring. Aluminum foil was secured over the cup tops to minimize evaporative loss. The cups were placed for 4 d in an incubator set at 20 °C. Following priming, the seeds and vermiculite were washed into a sieve that retained the seeds. Thorough rinsing with running, demineralized water removed the vermiculite.

The primed seeds were immediately transferred to 125 × 80 × 20-mm boxes containing two layers of germination paper (Seed Germination Blotter No. 385; Seedburo, Chicago) moistened with 15 mL of half-strength Hoagland solution (Hoagland and Arnon, 1950). Nonprimed seeds were included as controls. The 2 (seed species) × 5 (four priming treatments and nonprimed seeds) factorial with four replications of 50 seeds was arranged in a completely randomized design in darkness in an incubator set at 20 °C for the germination assay. This experiment and the subsequent two experiments were conducted once.

The numbers of seeds germinated (having visible coleorhiza or radicles) were recorded daily until no further germination occurred. From these data, the angular transformation of the final germination percentage (FGP), the days to 50% FGP (G_{50} , an inverse measure of germination rate), and the days between 10% and 90% FGP (G_{10-90} , an inverse measure of germination synchrony) were calculated and subjected to analysis of variance (ANOVA).

Experiment 2. Postpriming storage conditions. Using the lowest ratio of seeds to vermiculite determined in Expt. 1 to prime seeds adequately (1:10 for Kentucky bluegrass and 1:20 for tall fescue), seeds were matrically primed for 4 d at −1.5 MPa and 20 °C, as described in Expt. 1. The cups containing the primed seeds and moist vermiculite then were stored at 5 or 20 °C for 2, 4, 6, 8, or 10 d. The 20 °C storage represented a continuation of priming. Priming and storage were initiated at different times so that all storage periods ended at the same time. Following storage, the primed seeds were separated from the vermiculite by rinsing as described in Expt. 1.

The primed-stored seeds were transferred to germination boxes as described for Expt. 1. Both primed but nonstored seeds and nonprimed seeds were included in the germination assay. Germination boxes for treatments within a species were completely randomized with four replications of 50 seeds per treatment. The germination assay was conducted at 20 °C in darkness, and germination was assessed as described in Expt. 1.

Experiment 3. Seedling emergence and growth. The longest period of storage at either temperature that did not result in germination (10 d at 5 or 20 °C for Kentucky bluegrass; 10 d at 5 °C or 2 d at 20 °C for tall fescue) was selected for this experiment. Seeds were primed and stored as described in Expt. 2, except that each treatment was applied to 100 seeds and the masses of vermiculite and water were doubled correspondingly. The priming/stor-

Received for publication 20 Dec. 1996. Accepted for publication 7 Mar. 1997. Published as Paper No. 1596 in the Journal Series of the Delaware Agricultural Experiment Station. Contribution No. 330 of the Dept. of Plant and Soil Sciences. Mention of trade name or products in this publication implies neither endorsement by the Delaware Agricultural Expt. Station nor criticism of similar ones not mentioned. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked advertisement solely to indicate this fact.

age treatments were started at different times so that the seedling emergence assay started at the same time. Both primed but nonstored and nonprimed seeds were included in the emergence assay.

The seeds were sown into moistened proprietary peat-lite (Promix BX; Premier Brands, New Rochelle, N.Y.) contained in 17 × 12 × 6-cm plastic trays. Each treatment (tray) consisted of 100 seeds sown in five furrows 0.5 cm deep and 12 cm long. The seeded furrows were covered with 0.5 cm of moistened peat-lite. The flats were surface irrigated daily. The four seed treatments were arranged in a randomized block design with four replications in a greenhouse with natural light (May) set at 20 °C day/16 °C night. The numbers of seedlings emerged (coleoptile first visible) were recorded daily until no further emergence occurred. Final emergence percentage (FEP), days to 50% FEP (E_{50}), and days between 10% and 90% FEP (E_{10-90}) were calculated as described for germination in Expt. 1 and subjected to ANOVA. Shoots were cut at the peat-lite surface 14 d after sowing and shoot fresh and dry masses (65 °C for 1 week) were determined.

Results

Experiment 1. Seed : vermiculite ratio. Primed seeds of both species germinated faster (lower G_{50} values) than nonprimed at all seed : vermiculite ratios; but priming did not affect FGP or G_{10-90} (Table 1).

Experiment 2. Postpriming storage conditions. Storing primed Kentucky bluegrass seeds (1 seed : 10 vermiculite) in moist vermiculite for 10 d at either 5 or 20 °C did not reduce the rate or synchrony of subsequent germination (Table 2).

The G_{50} values of primed tall fescue seeds (1 seed : 20 vermiculite) after 10-d storage at 5 °C were similar to those of nonstored primed seeds; however, more than 10% of the primed seeds germinated in the vermiculite when stored at 20 °C for 4 or more days (Table 2). Storing primed seeds for 10 d at 5 °C or 2 d at 20 °C did not affect FGP or G_{10-90} values.

Experiment 3. Seedling emergence and growth. Seedlings developing from both stored or non-stored primed seeds of both species emerged faster (lower E_{50} values) and had higher shoot fresh and dry masses 14 d after sowing than did those from nonprimed seeds (Table 3). Storage of primed Kentucky bluegrass seeds did not affect either E_{50} or seedling shoot masses. However, storage of primed tall fescue seeds reduced E_{50} values (0.8-d average) and increased seedling shoot fresh and dry masses. Emergence synchrony and seedling shoot masses from primed (stored or nonstored) and nonprimed seeds of tall fescue were similar. Priming increased the E_{10-90} values of primed Kentucky bluegrass seeds regardless of storage period, and increased the FEP of primed seeds stored for 10 d at 20 °C.

Discussion

The lowest seed : vermiculite ratios (dry weight basis) to provide full priming benefit

Table 1. Final germination percentage (FGP) and its angular transformation (deg.), days to 50% of FGP (G_{50}), and days between 10% and 90% of FGP (G_{10-90}) of Kentucky bluegrass and tall fescue seeds at constant 20 °C in half-strength Hoagland solution. Seeds were matric primed at -1.5 MPa for 4 d at 20 °C in various seed : vermiculite mass ratios (Expt. 1).

Seed treatment ^a	Kentucky bluegrass			Tall fescue		
	G_{50} (days)	G_{10-90} (days)	FGP % (deg.)	G_{50} (days)	G_{10-90} (days)	FGP % (deg.)
1:10	4.4	3.7	90 (72)	2.3	2.3	91 (73)
1:20	4.7	3.8	85 (67)	1.6	1.6	93 (75)
1:30	4.8	4.0	88 (70)	1.6	1.6	94 (76)
1:40	4.0	3.6	85 (67)	1.6	1.7	94 (77)
Nonprimed	6.1	3.2	90 (71)	4.2	1.8	95 (78)
LSD _{0.05}	0.8*	NS	(NS)	0.2***	0.5*	(NS)

^aSeed : dry vermiculite mass ratios.

NS, *, ***Nonsignificant or significant at $P \leq 0.05$ or 0.001, respectively.

Table 2. Final germination percentage (FGP) and its angular transformation (deg.), days to 50% of FGP (G_{50}), and days between 10% and 90% of FGP (G_{10-90}) of Kentucky bluegrass and tall fescue seeds at constant 20 °C in half-strength Hoagland solution. Seeds were matric primed (-1.5 MPa for 4 d at 20 °C) then stored moist for up to 10 d at 5 or 20 °C (Expt. 2).

Storage conditions of primed seeds		Kentucky bluegrass			Tall fescue		
Temp (°C)	Time (days)	G_{50} (days)	G_{10-90} (days)	FGP % (deg.)	G_{50} (days)	G_{10-90} (days)	FGP % (deg.)
Nonprimed	---	6.3	3.1	89 (72)	4.0	2.2	94 (76)
---	0	4.2	3.5	93 (75)	1.3	1.8	97 (80)
5	2	4.3	3.6	88 (71)	1.5	1.2	96 (81)
5	4	4.7	3.7	86 (69)	1.5	1.8	96 (78)
5	6	4.3	3.5	92 (74)	1.3	2.0	90 (72)
5	8	3.7	3.9	87 (69)	1.2	1.9	95 (77)
5	10	4.4	3.3	90 (72)	1.0	1.7	92 (74)
20	2	4.2	4.1	86 (68)	0.8	1.7	95 (77)
20	4	4.4	3.3	88 (70)	---	---	---
20	6	4.2	4.1	94 (76)	---	---	---
20	8	4.1	3.1	85 (67)	---	---	---
20	10	4.1	3.3	91 (73)	---	---	---
LSD _{0.05}		0.5***	NS	(NS)	0.2***	0.7*	(NS)

---denotes excessive (>10%) germination during storage of the primed seeds.

NS, *, ***Nonsignificant or significant at $P \leq 0.05$ or 0.001, respectively.

Table 3. Final emergence percentage (FEP) and its angular transformation (deg.), days to 50% of FEP (E_{50}), days between 10% and 90% of FEP (E_{10-90}), and shoot fresh and dry mass of Kentucky bluegrass and tall fescue at 14 d after sowing seeds into peat-lite medium. Seeds were nonprimed or matric primed (-1.5 MPa for 4 d at 20 °C) with or without subsequent moist storage (Expt. 3).

Storage conditions of primed seeds					Shoot mass (mg/shoot)	
Temp (°C)	Time (days)	E_{50} (days)	E_{10-90} (days)	FEP % (deg.)	fresh	dry
Kentucky bluegrass						
Nonprimed	---	8.2	1.1	71 (57)	1.6	0.2
Nonstored	---	4.8	4.4	75 (60)	3.6	0.6
5	10	4.5	4.6	80 (63)	3.9	0.7
20	10	4.5	5.7	82 (65)	3.7	0.6
LSD _{0.05}		0.6***	3.8*	(6)*	0.6***	0.1***
Tall fescue						
Nonprimed	---	6.6	2.3	88 (70)	10.2	1.3
Nonstored	---	3.5	3.0	89 (71)	14.8	2.0
5	10	2.8	2.2	93 (74)	18.0	2.4
20	2	2.6	2.0	91 (72)	18.5	2.4
LSD _{0.05}		0.1***	NS	(NS)	3.0***	0.3***

NS, *, ***Nonsignificant or significant at $P \leq 0.05$ or 0.001, respectively.

for seeds of Kentucky bluegrass and tall fescue were 1:10 and 1:20, respectively (Table 1). The greater G_{50} of tall fescue seeds after priming at 1:10 than at 1:20 to 1:40 (seed : vermiculite) may indicate that insufficient water was available at 1:10 to hydrate the seeds adequately. Seeds of tall fescue may require more water than those of Kentucky bluegrass for maximal priming benefit; however, we did not monitor seed moisture con-

tent. Although the initial matric potential of the water-vermiculite mixture was nominally -1.5 MPa, as established by a moisture characteristic curve (Khan et al., 1990, 1992), matric potential values would decrease during priming owing to water removal by evaporation and seed imbibition. However, since the expanded vermiculite has a high water-holding capacity, a small decrease in water content would not influence the matric poten-

tial greatly.

The major effect of priming was increased germination rate in both species, a response previously noted in four fescue species (Frett and Pill, 1995), Kentucky bluegrass (Pill and Korengel, 1997), five other grass species (Hardegree, 1994; Maguire et al., 1992), and Italian ryegrass (*Lolium multiflorum* Lam., Danneberger et al., 1992). The germination advancement due to priming of grass seeds was greater at suboptimal than at optimal germination temperatures (Adegbuyi et al., 1981; Danneberger et al., 1992; Frett and Pill, 1995). Under more extreme germination conditions than used in the present study (constant 20 °C), the response to priming might have been greater. For instance, increased grass seed germination as a result of priming was noted at high temperature (Frett and Pill, 1995), low temperature (Adegbuyi et al., 1981), and reduced water availability (Frett and Pill, 1995; Hardegree and Emmerich, 1992).

Promotion of germination rate by priming in both species after 2 to 10 d of moist storage at 5 °C (Table 2) revealed that physiological and biochemical processes associated with priming (Khan, 1992; Parera and Cantliffe, 1994; Pill, 1994) were retained during refrigerated storage. Storage of primed seeds at 20 °C in vermiculite prolonged priming. Thus, Kentucky bluegrass seeds could be primed for 14 d at 20 °C with no loss of effect. The reduction of G₅₀ in primed tall fescue seeds by 2-d storage at 20 °C may indicate that during storage (an effective 6-d priming period) the seeds had absorbed considerable water (phase III imbibition), leading to radicle elongation. Consequently, germination was excessive.

Traditionally, primed seeds are dried before sowing; however, some of the priming benefit is lost with drying. For instance, Pill and Korengel (1997) noted that although germination of primed Kentucky bluegrass seeds was slowed by drying, the primed and dried seeds germinated faster than nonprimed seeds. Hardegree (1994) noted that, although germination of primed native bunchgrass seeds was reduced by drying and 11 weeks of storage, it still surpassed that of nonprimed seeds. Brocklehurst et al. (1984) suggested that drying primed seeds of leek (*Allium porrum* L.) reduced germination by increasing the time need for reimbibition.

More rapid seedling emergence from primed (stored or nonstored) than from nonprimed seeds of Kentucky bluegrass or tall fescue led to greater seedling shoot fresh and dry masses (Table 3) as reported previously for four fescue species (Frett and Pill, 1995) and Kentucky bluegrass (Pill and Korengel, 1997). Greater seedling shoot mass from matrically primed seeds than from nonprimed seeds of Kentucky bluegrass was due to the advancement in germination and not to a

stimulation of growth, since seedling relative growth rate was unaffected by priming (Pill and Korengel, 1997).

Vermiculite is sufficiently dry at -1.5 MPa to permit easy dispersal of the seed-vermiculite mixture without drying, which may delay subsequent germination. Both the moisture content of primed seeds at time of planting and seedbed moisture content can influence stand establishment. For instance, Beckman et al. (1993) noted that percentage of seedling emergence from high-moisture (nondried) primed seeds of *Panicum virgatum* L. was greater than that of untreated seeds in a moist seedbed but lower in a dry seedbed. Seedlings from matrically primed seeds of four fescue species emerged faster than those from nonprimed seeds in both wet and dry seedbeds; while seedling shoot dry masses of all species were greater in the dry medium, those of only two species were greater in the wet seedbed (Frett and Pill, 1995).

The results of our studies have established that the major effect of matric priming of seeds of both Kentucky bluegrass and tall fescue was the advancement of germination or seedling emergence and the consequent increase in early seedling growth. The increase in germination rate was maintained in both species after storing the primed seeds in moist vermiculite for up to 10 d at 5 °C. With storage at 20 °C, the benefit of priming was retained for up to 10 d in Kentucky bluegrass, but for only 2 d in tall fescue.

The need to remove the salt or polyethylene from seeds following osmotic priming is avoided when seeds are matrically primed. Matric priming eliminates the problem of low seed aeration that can occur when seeds are bulk primed in polyethylene glycol (Mexal et al., 1975) and avoids the problem of "underpriming" that can result when seeds are primed in salt solutions (Haigh and Barlow, 1987). The primed seed and moist vermiculite may be sown together, perhaps with more vermiculite added to the mixture to aid seed dispersal. Since the seeds and vermiculite are of similar density, minimal separation of the two would be expected at the time of seed broadcasting. Sowing such a mixture should speed turf stand establishment by promoting early seed germination and early seedling growth.

Literature Cited

- Adegbuyi, E., S.E. Cooper, and R. Don. 1981. Osmotic priming of some herbage grass seed using polyethylene glycol (PEG). Seed Sci. and Technol. 9:867-878.
- Beckman, J.J., J.E. Moser, K. Kubik, and S.S. Waller. 1993. Big bluestem and switchgrass establishment as influenced by seed priming. Agron. J. 85:199-202.
- Brocklehurst, P.A., J. Dearman, and R.L.K. Drew. 1984. Effects of osmotic priming on seed germination and seedling growth in leek. Scientia Hort. 24:201-210.
- Danneberger, T.K., M.B. McDonald, C.A. Geron, and P. Kumari. 1992. Rate of germination and seedling growth of perennial ryegrass seed following osmoconditioning. HortScience 27:28-30.
- Dudeck, A.E. and H. Peacock. 1986. Pregermination of Italian ryegrass and tall fescue seed. Crop Sci. 26:177-179.
- Evans, T.A. and W.G. Pill. 1989. Emergence and seedling growth from osmotically primed or pregerminated seeds of asparagus (*Asparagus officinalis* L.). J. Hort. Sci. 64:275-282.
- Frett, J.J. and W.G. Pill. 1989. Germination characteristics of osmotically primed and stored *Impatiens* seeds. Scientia Hort. 40:171-179.
- Frett, J.J. and W.G. Pill. 1995. Improved seed performance of four fescue species with priming. J. Turfgrass Mgt. 1:13-31.
- Haigh, A.M. and E.W.R. Barlow. 1987. Germination and priming of tomato, carrot, onion and sorghum seeds in a range of osmotica. J. Amer. Soc. Hort. Sci. 112:202-208.
- Hardegree, S.P. 1994. Drying and storage effects on germination of primed grass seeds. J. Range Mgt. 47:196-199.
- Hardegree, S.P. and W.E. Emmerich. 1992. Seed germination response of four southwestern range grasses to equilibration at subgermination matric potentials. Agron. J. 84:994-998.
- Hoagland, D.R. and D.I. Arnon. 1950. The water culture method for growing plants without soil. Calif. Agr. Expt. Sta. Circ. 47.
- Khan, A.A. 1992. Preplant physiological seed conditioning. Hort. Rev. 13:131-181.
- Khan, A.A., J.D. Maguire, G.S. Abawi, and S. Ilyas. 1992. Matricconditioning of vegetable seeds to improve stand establishment in early field plantings. J. Amer. Soc. Hort. Sci. 117:41-47.
- Khan, A.A., H. Miura, J. Prusinski, and S. Ilyas. 1990. Matricconditioning of seeds to improve emergence, p. 19-40. In: Proc. Natl. Symp. on Stand Establishment of Hort. Crops. Minneapolis.
- Lush, W.M. and J.A. Birkenhead. 1987. Establishment of turf using advanced ('pregerminated') seeds. Austral. J. Expt. Agr. 27:323-327.
- Maguire, J.D., W.J. Johnston, E.S. Maring, and C.D. Burrows. 1992. Enhanced performance of grass seed by matricconditioning. Proc. 101, Natl. Symp. Stand Establishment Hort. Crops, Univ. of Florida. p. 317-23.
- Mexal, J., J.T. Fisher, J. Osteryoung, and C.P. Reid. 1975. Oxygen availability in polyethylene glycol solutions and its implication in plant-water relations. Plant Physiol. 55:20-24.
- Parera, C.A. and D.J. Cantliffe. 1994. Presowing seed priming. Hort. Rev. 16:109-141.
- Pill, W.G. 1994. Low water potential and presowing germination treatments to improve seed quality, p. 319-359. In: A.S. Basra (ed.). Seed quality: Basic mechanisms and agricultural implications. Haworth Press, Binghampton, N.Y.
- Pill, W.G. and W.E. Finch-Savage. 1988. Effects of combining priming and plant growth regulator treatments on the synchronisation of carrot seed germination. Ann. Appl. Biol. 114:383-389.
- Pill, W.G. and T.K. Korengel. 1997. Seed priming advances the germination of Kentucky bluegrass (*Poa pratensis* L.). J. Turfgrass Mgt. 2:27-43.