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Responses of Six Wildflower Species to Seed Matric Priming[1]

Wallace G. Pill, Renee H. Bender, Adrienne C. Pie, Josh K. Marvel, and Erin E. Veacock[2]
Department of Plant and Soil Sciences, University of Delaware
Newark, Delaware 19717-1303

Abstract

Seeds of six wildflower species [*Aster novae-angliae* (New England aster), *Rudbeckia hirta* (Black-eyed Susan), *Liatris spicata* (Blazing star), *Hesperis natronalis* (Dame's rocket), *Gaillardia aristata* (Perennial gaillardia), and *Asclepias tuberosa* (Butterfly weed)] were matrically primed in fine, exfoliated vermiculite. Seeds were primed for 7 days at 15C (59F) at an initial matric potential of –0.5 MPa (–5 bars) in darkness, then dried for 7 days before sowing. A seed:vermiculite (1:2 by wt) ratio was found to be the most appropriate of several ratios because it increased germination rate of all species except Black-eyed Susan, increased the germination percentage of Perennial gaillardia, and prevented germination of Dame's rocket and Perennial gaillardia during priming. Under restricted water availability [–0.25 and –0.50 MPa (–2.5 and –5.0 bars)] priming increased the germination percentage of Perennial gaillardia and Butterfly weed and increased the germination rate of all species. In a glasshouse study, priming increased the emergence percentage of Perennial gaillardia and increased the emergence rate of all species. Compared with hydration of the vermiculite with water, using 10^{-3} M gibberellic acid during priming increased the emergence rate of Dame's rocket, increased the emergence percentage of Perennial gaillardia, and increased the shoot dry weights of New England aster and Black-eyed Susan.

Index words: gibberellic acid, seed germination, seedling emergence.

Species used in this study: New England aster (Aster novae-angliae L.); Black-eyed Susan (Rudbeckia hirta L.); Blazing star (*Liatris spicata* Willd.); Dame's Rocket (*Hesperis natronalis* L.); Perennial gaillardia (*Gaillardia aristata* Pursh.); Butterfly weed (*Asclepias tuberosa* L.).

Chemicals used in this study: Pro-Gibb (gibberellic acid, GA_3).

Significance to the Nursery Industry

Matric priming of seeds increased seedling emergence rate of six wildflower species which would reduce the time for plug production, or wildflower meadow establishment. Seeds were mixed in fine vermiculite at 1 seed:2 vermiculite by weight. Water equal to the weight of the vermiculite was stirred into the seed-vermiculite mixture. For broadcast sowing of a seed species or species mixture, the seed and vermiculite may be sown together with more dry vermiculite added to aid seed dispersal. Such a mixture could be sown immediately after seed priming. For plug sowing where sowing single seeds is important, the seeds are readily separated from the vermiculite by sieving. Inclusion of gibberellic acid during priming would not be justified since it exerted a minimal effect on seedling emergence and growth.

Introduction

Wildflowers provide aesthetic appeal and a habitat and food for wildlife and are a source of cut flowers. The production and sale of potted herbaceous perennials has been one of the greatest opportunities for economic success in the nursery industry in recent years (22). Considerable constraints on sowing wildflower seeds exist, including high seed costs and variable, often poor establishment (24).

Seed priming might improve wildflower crop establishment. Priming involves seed exposure to a low water potential created osmotically in salt or polyethylene glycol (PEG) solutions or matrically by exposure to moistened solid materials with high water adsorptive capillary forces (16). For instance, low-vigor seeds of *Rudbeckia fulgida* primed in –1.3 MPa (–13 bars) KNO_3 had double the total germination percentage at 30C (86F) and one-half the mean time of germination as non-primed seeds (5). Osmotic priming increased percentage emergence of *Echinacea purpurea* but not that of *Coreopsis lanceolata*, and greatly increased seedling total root area (7). Samfield et al. (22) noted that the uniformity and advancement of germination, and seedling emergence was improved by osmotically priming *Echinacea purpurea* and *Coreopsis lanceolata* seeds. Osmotic priming of seeds of *Salvia splendens* (3) and of pansy (*Viola* x *wittrockiana*) (4) increased germination rate and extended the temperature range through which seed germination could occur. Enhanced vigor of primed seeds compared to that of non-primed seeds has increased the rate, synchrony and percentage seedling emergence under such adverse seedbed conditions as low temperature (17), high temperature (3, 4), reduced water availability (9) or salinity (18). Tallowin et al. (25) tested the response of 61 wild flower species (21 families) to priming in PEG. Although priming reduced the median germination time of all species, germination percentage was increased in 15 species, and was decreased in eight species. They noted no clear patterns in response to priming in relation to either species' ecology or plant family.

Finch-Savage (6) noted that combining osmotic priming with a plant growth regulator treatment increased germination rate of four bedding plant species, and increased germination percentage of two species. Gibberellic acid (GA_{4+7} at 10^{-4} or 10^{-6} M) was most effective when added to the priming solution than when applied as a pre-soak. Pill and Haynes (20) noted that 10^{-6} M GA_3 during matric priming enhanced the benefits of priming by increasing further the emergence rate and synchrony, seedling shoot dry weight, and petiole

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[2]Professor and undergraduate students, resp.

and lamina lengths of the first true leaf. Andreoli and Khan (1) reported synergistic promotion of germination and seedling emergence of papaya (*Carica papaya* L.) by combining matric priming and GA_{4+7} treatment. Madakadze et al. (13) noted greater rate and percentage of germination of *Bupleurum griffithii* (a tropical herbaceous cut flower) from matric priming in a synthetic silicate than in vermiculite or osmotic priming in PEG. Including 10^{-3} M GA_{4+7} during osmotic priming (PEG) advanced germination but not during matric priming.

The purpose of the present study was to determine the effect of seed:vermiculite ratio and GA_3 concentrations during matric priming of six wildflower species on germination and seedling emergence, and on early seedling growth.

Materials and Methods

Seed:vermiculite ratio and gibberellic acid concentration. Seeds of six wild flower species were purchased (February) and stored at 20C (68F) and 35% relative humidity for one month prior to the studies. The names, seed weight and seed size of the species are listed in Table 1. Each treatment consisted of 100 seeds, replicated four times. Some seeds received a 48-hour exposure to 0, 10^{-6} and 10^{-3} M gibberellic acid (GA_3, ProGibb Plus 2X, Abbott Laboratories, Chicago, IL). The seeds were placed on double layers of germination paper (Seed Germination Blotters No. 385, Seedburo Co., Chicago, IL) in 125 × 80 × 20 mm (4.9 × 3.1 × 0.8 in) transparent polystyrene boxes. The blotters were saturated with the solutions. Seeds of each species were matrically primed in No. 5 fine vermiculite (W.R. Grace, Cambridge, MA) at seed:vermiculite weight ratios of 0.5, 1.0, 2.0, 4.0, or 6.0. A matric potential of –0.5 MPa (–5 bars) was achieved by hydrating the vermiculite with 100% (w/w) with solutions of the three GA_3 concentrations according to a moisture characteristic curve (12). This matric potential successfully primed *Echinacea purpurea* seeds (19, 20) and gave higher germination rate and percentage than a lower (–1.5 MPa) matric potential (19). The seeds were added to the moistened vermiculite contained in 25-ml (0.9 oz) plastic souffle cups (Solo Cup Company, Urbana, IL) or in 1.5 × 3.5 cm (0.6 × 1.4 in) vials for the very small seeds of New England aster and Black-eyed Susan. The seeds, liquid and vermiculite were mixed thoroughly by stirring, and aluminum foil secured over the cup or vial tops to minimize evaporative loss. Following the 7-day priming period at 15C (59F) in darkness, the seeds and vermiculite were washed into a sieve that retained the seeds, and the seeds were rinsed thoroughly with running demineralized water. Some seeds of New England aster and Black-eyed Susan were lost during sieving, but the retained seed (>50) were counted. Seeds from each treatment were dried for 1 week at 25C (77F) and 35% relative humidity. All treatments were scheduled so that the germination assay began on the same day. For the germination assay, seeds were transferred to boxes (described above) containing two layers of germination paper saturated with 15 ml (0.5 fl oz) of half-strength Hoagland solution (10) to mimic soil ionic strength. Germination boxes were arranged in completely randomized design in incubators set at 25C (77F) in darkness. The number of seeds germinated (having visible radicles) was recorded daily until no further germination occurred. From these data, the angular transformation of the final germination percentage (FGP) and days to 50% FGP (G_{50}, an inverse measure of germination rate) were calculated and subjected to one-way analysis of variance.

Germination with restricted water supply. Seeds of each species were matrically primed in vermiculite (1 seed:2 vermiculite) moistened with 0, 10^{-6}, or 10^{-3} M GA_3 for 7 days [–0.5 MPa (–5 bars), 15C (59F)] as described above. The primed then dried seeds [1 week at 25C (77F) and 35% relative humidity] were subjected to 0, –0.25 or –0.50 MPa (0, –2.5 or –5.0 bars) water potential created by adding 0, 130 or 202 g (0, 4.6 or 7.1 oz) of PEG, respectively, to each kg (35.3 oz) (14) of half-strength Hoagland solution. The germination assay was conducted at 25C (77F) in darkness in boxes containing double layers of germination paper saturated with the PEG solutions. The experimental design, data collection and analyses were as described above.

Seedling emergence. The treatments described immediately above were repeated. The seeds were sown in moistened peat-lite (Redi-Earth Plug and Seedling Mix, Scotts-Sierra, Marysville, OH) contained in 17 × 12 × 6 cm (6.7 × 4.7 × 2.4 in) plastic trays. Each treatment (tray) consisted of 100 seeds sown in five furrows 0.5 cm (0.2 in) deep and 12 cm (4.7 in) long. Seeds of New England aster and Black-eyed Susan were covered with 2 mm (0.08 in) of the peat-lite, but the other species were covered with 0.5 cm (0.2 in). The trays were surface irrigated daily. The seven treatments were arranged in randomized block design with four replications in a glasshouse with natural light (May) set at 20/16C (68/61F) day/night. The numbers of seedlings emerged (hypocotyl first visible) were recorded daily until no further emergence occurred. Final emergence percentage (FEP) and days to 50% FEP (E_{50}, an inverse measure of emergence rate) were calculated. At 16 days after planting, shoots were thinned by cut-

Table 1. Species used in the study and selected seed characteristics.

Binomial name	Common name	100 seeds (mg)	Seeds per g	Seed, greatest dimensions (mm)
Aster novae-angliae L.	New England aster	35	2857	2.5 × 1.5 × 1.5
Rudbeckia hirta L.	Black-eyed Susan	37	2703	2.0 × 0.5 × 0.5
Liatris spicata Willd.	Blazing star	304	329	5.0 × 1.5 × 1.5[z]
Hesperis natronalis L.	Dame's rocket	237	422	2.5 × 1.5 × 1.5
Gaillardia aristata Pursh.	Perennial gaillardia	311	322	3.0 × 2.0 × 2.0[y]
Asclepias tuberosa L.	Butterfly weed	675	148	5.0 × 2.5 × 0.7[x]

[z]Distal pappus approximately doubled seed length and widths

[y]Distal pappus approximately tripled seed length and doubled seed widths

[x]Wing pappus surrounding the seed laterally increased seed size to 6.0 × 3.5 × 0.7 mm

Table 2. Final germination percentage (FGP) and days to 50% of FGP (E_{50}) of seeds of six wildflower species in response to seed:vermiculite weight ratio during matric priming.

Seed:vermiculite	Wildflower species					
	Dame's rocket	Butterfly weed	New England aster	Perennial gaillardia	Black-eyed Susan	Blazing star
	Final germination [% (deg.)]					
1:0.5	90 (72)	58 (49)	41 (40)	44 (42)	74 (59)	76 (61)
1:1	91 (73)	59 (50)	44 (41)	54 (47)	76 (61)	77 (61)
1:2	91 (72)	58 (50)	46 (42)	59 (50)	68 (56)	78 (62)
1:4	92 (74)	0 (—)	47 (43)	54 (47)	64 (53)	78 (62)
1:6	0 (—)	0 (—)	42 (41)	57 (49)	64 (53)	77 (61)
Non-treated seeds	90 (72)	62 (52)	42 (41)	40 (39)	91 (73)	78 (62)
$LSD_{0.05}$[z]	(3)[NS]	(3)[NS]	(3)[NS]	(3)[***]	(2)[*]	(2)[NS]
	G_{50} (days)					
1:0.5	1.9	2.6	2.8	3.5	3.3	4.2
1:1	1.7	2.3	2.6	3.5	3.4	3.2
1:2	1.4	2.1	2.6	2.8	3.1	2.5
1:4	1.3	—	2.7	2.8	2.9	2.5
1:6	—[y]	—	2.8	2.5	2.9	1.9
Non-treated seeds	2.3	2.8	3.8	4.0	2.4	4.7
$LSD_{0.05}$[z]	0.7[***]	0.1[***]	0.4[NS]	0.2[***]	0.2[*]	0.2[***]

[z]***, NS: Significant at $P \leq 0.001$ or not significant, respectively.

[y]— = not applicable due to 0% germination.

ting them at the peat-lite surface to leave six equally placed shoots. At 40 days after planting, these shoots were cut at the peat-lite surface and dried [1 week at 65C (149F)] for shoot dry weight determination. All data were subjected to one-way analysis of variance.

Results and Discussion

Seed:vermiculite ratio and gibberellic acid concentration. Priming, irrespective of seed:vermiculite ratio, increased the FGP of Perennial gaillardia, decreased the FGP of Black-eyed Susan, and had no effect on that of the other species (Table 2). Tallowin et al. (25) likewise reported a varying response of 60 wildflower species to priming; the final germination of 15 species was increased, while that of eight was decreased. Priming increased the germination of *Echinacea purpurea* (7, 19, 20, 27), *Coreopsis lanceolata* (7), and *Rudbeckia fulgida* (5). The increased FGP of Perennial gaillardia with priming was accompanied by decreased G_{50} which was more pronounced when the seed:vermiculite was <1:1. Sufficient volume of vermiculite was needed to cover the Perennial gaillardia seeds, whose pappus doubled seed length (Table 1). For Black-eyed Susan, the lower FGP and higher G_{50} of primed than those of non-primed seeds indicated a toxic response to priming. These seeds may have reached the desiccation intolerant stage of imbibition during priming so that seed viability decreased during post-priming drying. Increased fungal contamination during priming may have decreased germination as noted for primed *Cucumis melo* L. seeds (15). Decreased germination of primed RH seeds could not be attributed to low seed size or weight alone since similarly sized primed AN seeds (Table 1) germinated faster than non-primed seeds, and priming had no effect on FGP.

During matric priming, water is lost from the solid carrier owing to seed imbibition and limited evaporation. At low seed:vermiculite ratio, seeds of Dame's rocket (1:6) and Butterfly weed (1:4 and 1:6) had absorbed sufficient water to cause germination (Table 2). Greater seed:vermiculite ratios prevented germination because during imbibition (and evaporative loss), the water concentration of the vermiculite would decrease more rapidly and to a greater extent so that less water would be available to the seeds. Germination in the matrix also could be prevented by lowering the initial matric potential of the vermiculite, decreasing the priming temperature, or decreasing the priming duration. Warren and Bennett (26) described a drum priming system that, based on initial and desired hydrated seed weights, hydrated seeds to the desired moisture concentration by intermittently injecting water into seeds within a revolving drum. This system avoided problems associated with seed:vermiculite ratio and initial matric potential of the vermiculite.

Maximum germination of the species tested may not have been realized in this study since the priming treatments may not substitute for other pregermination treatments such as chilling, temperature conditions, KNO_3 treatment, scarification, or light/dark regimes that may be required. Standard germination testing procedures (11) recommend prechilling for New England aster, Perennial gaillardia, Dame's rocket and Black-eyed Susan, light for Perennial gaillardia and Black-eyed Susan, and 0.2% KNO_3 (w/v) for Dame's rocket. For instance, priming enhanced the germination percentage of stratified seeds of *Aquiligea canadensis* (8).

We selected 1 seed:2 vermiculite as the most appropriate ratio for priming the six species of this study since it lowered the G_{50} of all but one species (Black-eyed Susan) and increased the FGP of Perennial gaillardia. Lower ratios pre-

Table 3. Final germination percentage (FGP) and days to 50% of FGP (E_{50}) of matrically primed seeds of six wildflower species in response to restricted water supply during the germination assay.

Seed treatment	Matric potential during germination (MPa)	Wildflower species					
		Dame's rocket	Butterfly weed	New England aster	Perennial gaillardia	Black-eyed Susan	Blazing star
		Final germination [% (deg.)]					
Non-primed	0	67 (55)	59 (50)	30 (32)	41 (40)	87 (69)	82 (65)
	–0.25	43 (41)	51 (46)	8 (16)	46 (43)	80 (64)	76 (60)
	–0.50	14 (22)	48 (44)	0(—[z])	18 (25)	59 (50)	71 (58)
Primed (0 m GA_3)	0	56 (49)	56 (49)	47 (43)	63 (53)	71 (58)	74 (60)
	–0.25	33 (35)	59 (50)	45 (42)	54 (47)	66 (55)	73 (59)
	–0.50	12 (20)	48 (44)	20 (27)	37 (37)	45 (42)	70 (57)
Primed (10^{-6} M GA_3)	0	53 (47)	58 (50)	41 (40)	59 (50)	71 (57)	79 (63)
	–0.25	35 (36)	60 (51)	37 (38)	52 (46)	62 (52)	75 (60)
	–0.50	18 (25)	48 (44)	14 (22)	43 (41)	49 (44)	71 (57)
Primed (10^{-3} M GA_3)	0	68 (56)	57 (49)	44 (41)	66 (54)	79 (63)	82 (65)
	–0.25	56 (48)	50 (45)	45 (42)	62 (52)	79 (63)	76 (60)
	–0.50	21 (27)	48 (44)	23 (28)	38 (38)	62 (52)	67 (55)
$LSD_{0.05}$ 1-way		(6)	(6)	(10)	(5)	(8)	(7)
Significance[y]							
Seed treatment (ST)		***	NS	***	***	***	NS
Water potential (WP)		***	***	***	***	***	**
ST × WP		NS	NS	NS	*	NS	*
		G_{50} (days)					
Non-primed	0	1.2	1.7	3.0	4.6	1.9	4.2
	–0.25	2.1	2.9	4.3	4.6	2.9	4.9
	–0.50	3.6	3.2	—[y]	6.6	4.6	6.2
Primed (0 M GA_3)	0	0.6	0.8	1.2	2.0	1.9	1.8
	–0.25	0.8	0.8	2.3	2.2	2.1	2.7
	–0.50	3.0	1.7	4.5	3.9	2.9	4.0
Primed (10^{-6} M GA_3)	0	0.6	0.6	1.1	2.0	1.8	1.8
	–0.25	0.6	0.8	2.1	2.9	2.3	2.3
	–0.50	2.4	2.1	3.7	4.4	2.9	3.6
Primed (10^{-3} M GA_3)	0	0.5	0.6	2.0	2.0	1.7	2.1
	–0.25	0.7	0.7	1.9	2.7	2.2	2.7
	–0.50	2.8	1.4	4.4	3.6	2.9	4.1
$LSD_{0.05}$ 1-way		0.5	0.6	0.8	0.8	0.6	0.4
Significance[y]							
Seed treatment (ST)		***	***	***	***	***	***
Water potential (WP)		***	***	***	***	***	***
ST × WP		NS	*	NS	NS	**	NS

[z]— = not applicable due to 0% germination.

[y]***, **, *, NS: Significant at $P \leq 0.001$, 0.01, 0.05, or not significant, respectively

vented germination of Dame's rocket (1:6) and Butterfly weed (1:4 and 1:6). If seeds of these species were to be sown as a mixture as in the production of wildflower sod or a wildflower meadow, the vermiculite would be added at 2× the combined seed weights. Seed treatment with fungicides before priming may enhance seed performance (12, 15).

Inclusion of 10^{-3} M GA_3 compared with 0 M GA_3 in the vermiculite had no effect on FGP but slightly decreased the G_{50} of New England aster by 0.4 days and of Blazing star by 0.3 days (data not shown). Pill and Haynes (20) noted that 3 × 10^{-3} M GA_3 during osmotic or matric priming of *Echinacea purpurea* seeds increased the rate and synchrony of the primed seeds. Andreoli and Khan (1) reported synergistic promotion of germination of *Carica papaya* L. by combining matric priming and GA_{4+7} treatment. Madakadze et al. (13) noted increased germination rate by including 10^{-3} M GA_{4+7} during osmotic priming of *Bupleurum griffithii* seeds.

Germination with restricted water supply. Germination responses of primed [1 seed:2 vermiculite ratio, 7 days, 15C (59F), –0.5 MPa (–5 bars)] then dried seeds of all six species at 25C (77F) and water potentials of 0, –0.25 or –0.50 MPa (0, –2.5, or –5 bars) are shown in Table 3. Decreasing water availability generally decreased FGP and increased G_{50} of

Table 4. Final emergence percentage (FEP), days to 50% of FEP (E_{50}), and shoot dry weight of matrically primed seeds of six wildflower species in response to gibberellic acid (GA_3) during priming.

Seed treatment	Wildflower species					
	Dame's rocket	Butterfly weed	New England aster	Perennial gaillardia	Black-eyed Susan	Blazing star
	Final emergence [% (deg.)]					
1:0.5	90 (72)	58 (49)	41 (40)	44 (42)	74 (59)	76 (61)
Non-primed	87 (69)	54 (47)	53 (47)	34 (53)	81 (64)	82 (65)
Primed (0 M GA_3)	98 (85)	55 (48)	43 (41)	57 (49)	82 (65)	81 (64)
Primed (10^{-6} M GA_3)	97 (85)	54 (47)	53 (47)	57 (46)	83 (66)	85 (67)
Primed (10^{-3} M GA_3)	92 (75)	50 (45)	48 (44)	51 (49)	77 (61)	85 (68)
$LSD_{0.05}$ 1-way[z]	$(15)^{NS}$	$(4)^{NS}$	$(9)^{NS}$	$(9)^{*}$	$(5)^{NS}$	$(9)^{NS}$
	E_{50} (days)					
Non-primed	4.2	7.7	7.7	6.3	4.0	7.9
Primed (0 M GA_3)	3.6	6.0	4.9	4.6	3.7	4.4
Primed (10^{-6} M GA_3)	3.5	5.9	3.9	4.1	3.7	4.2
Primed (10^{-3} M GA_3)	3.3	5.9	3.9	4.0	3.5	4.4
$LSD_{0.05}$ 1-way[z]	0.2^{***}	0.3^{***}	1.1^{***}	1.0^{**}	0.2^{**}	0.5^{***}
	Shoot dry weight, 40 days after planting (mg/shoot)					
Non-treated	739	248	218	506	815	227
Prime 0 M GA3	749	301	308	714	863	326
Prime 10^{-6} M GA3	774	353	352	696	852	368
Prime 10^{-3} M GA3	713	319	399	711	990	347
$LSD_{0.05}$ 1-way[z]	107^{NS}	51^{*}	66^{***}	79^{***}	113^{*}	67^{**}

[z]***, **, *, NS: Significant at $P \leq 0.001$, 0.01, 0.05, or not significant, respectively.

primed and non-primed seeds. Primed seeds of Perennial gaillardia and New England aster, irrespective of GA_3 concentration, had greater FGP than non-primed seeds at every water potential, but priming failed to increase the germination of other species. Priming increased the germination rate of Butterfly weed, New England aster, Perennial gaillardia and Blazing star each water potential but increased germination rate of Dame's rocket and Black-eyed Susan at –0.25 and –0.50 MPa (–2.5 and –5.0 bars). Frett and Pill (9) reported that the beneficial effects of priming *Impatiens wallerana* seeds were most pronounced when germination occurred during the combined stresses of reduced temperature and reduced water availability. Enhanced vigor of primed seeds compared to non-primed seeds has increased the rate, synchrony and percentage of seedling emergence under such adverse seedbed conditions as low temperature (17), high temperature (3, 4), or salinity (18).

S*eedling emergence*. Priming increased the FEP of Perennial gaillardia from 34% to 55%, but failed to increase the FEP of the other species (Table 4). FEP was unaffected by GA_3 concentration during priming. Priming increased the emergence rate of all species, and 10^{-3} M GA_3 during priming resulted in slightly lower E_{50} than 0 M GA_3 only of Dame's rocket. Shoot dry weights of all species except Dame's rocket were increased by priming. Greater shoot dry weights due to priming was associated with lower E_{50}, a response that may be attributed to more rapid seedling emergence rather to increased seedling relative growth rates, as observed in *Allium porrum* (2) and in *Poa pratensis* (21). Inclusion of 10^{-3} M GA_3 compared to 0 M GA_3 during priming increased shoot dry weights of Black-eyed Susan and New England aster, but GA_3 concentration had no effect on shoot dry weight of the other species. Shoot height of only New England aster was increased by priming, and GA_3 concentration had no effect on shoot height of any species (data not shown). Inclusion of GA_3 during priming has stimulated hypocotyl growth of *Phaseolus vulgaris* (12) and of leaf petiole and lamina growth of *Echinacea purpurea* (20).

The results of these studies have shown that matric priming increased seedling emergence rate of all six species, but generally had no effect on percentage seedling emergence. Inclusion of gibberellic acid during priming would not be justified since it exerted such a minimal effect on seedling emergence and growth. The least amount of fine vermiculite that could provide a common benefit to priming seeds of all six species was 1 seed:2 vermiculite. For a seed mixture, the combined weight of the seeds of all species would be mixed with double the seed weight of dry vermiculite. Water equal to the weight of vermiculite would be mixed in the seed-vermiculite mixture. Using a 1 seed:2 vermiculite ratio, 1 liter (25.3 oz) of vermiculite would prime 235,700 seeds of New England aster (the lightest seed) to 12,200 seeds of Butterfly weed (the heaviest seed). For broadcast sowing of a seed species or species mixture, the seed and vermiculite may be sown together with more dry vermiculite added to aid seed dispersal. Such a mixture could be sown immediately after seed priming. For plug sowing where sowing single seeds is important, the seeds are readily separated from the vermiculite by sieving.

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