Abstract. The effects of various drying conditions on seed quality and performance of matriconditioned ‘Bush Blue Lake 47’ snap bean (Phaseolus vulgaris L.) seeds were studied. An exponential model based on the Page equation provided a good fit (R² = 0.9) to changes in moisture content during drying. Drying matriconditioned seeds with high initial moisture content (47.2%) for 5 to 6 hours at 35°C, 30% to 35% relative humidity, and 0.7 to 1.4 m·s⁻¹ air velocity (v) retained, and in some cases augmented, the benefits derived from conditioning. Matriconditioning greatly reduced electrolyte leakage (34.3 vs. 94.7 µS·cm⁻¹·g⁻¹ for nontreated seeds); drying to 15% moisture content at 0.7 or 1.4 m·s⁻¹ v moderately increased the leakage rate (59.1 to 60.9 vs. 34.3 µS·cm⁻¹·g⁻¹), while drying at 0.02 m·s⁻¹ (ambient) increased the rate to that of nontreated seeds. The leakage rate remained low (43.6 to 50.8 µS·cm⁻¹·g⁻¹) in matriconditioned seeds dried to 22% moisture content at all air velocities. In growth-chamber studies, rapidly drying matriconditioned seeds to 15% moisture content at 1.4 m·s⁻¹ v improved the emergence percentage over that of nontreated seeds, increased the shoot fresh and dry weight over that of nontreated and nondried matriconditioned seeds, and increased the shoot fresh weight over that of seeds dried at 0.02 or 0.7 m·s⁻¹ v. Drying matriconditioned seeds to 15% moisture content at 0.7 m·s⁻¹ v improved plant fresh weight over that produced by nontreated seeds. Rapid drying to 22% moisture content at 1.4 or 0.7 m·s⁻¹ v improved only shoot fresh weight over that of nontreated seeds. In a 1992 field planting, percent emergence of matriconditioned seeds dried at 0.7 or 1.4 m·s⁻¹ v was similar to that of nondried matriconditioned seeds and higher than that of nontreated seeds. No significant differences were noted in plant yield among the treatments.

Osmoconditioning (osmotic priming) seeds in a liquid medium has been used to shorten germination time, synchronize emergence, and improve stand and yield (Bradford, 1986; Heydecker and Coolbear, 1977; Khan et al., 1978, 1992). Recently, moist, solid carriers (vermiculite, expanded calcined clay, Micro-Cel E (a synthetic calcium silicate) (Manville, Denver)) with matric properties have been used to matricondition vegetable and flower seeds before planting (Bennett and Waters, 1984, 1987; Khan, 1992; Khan et al., 1990; Kubik et al., 1988). Empirical approaches have been used to dry seeds after conditioning, but little or no attention has been given to the influences of factors such as low vs. high relative humidity (RH), low vs. high air velocity (v), slow vs. rapid drying, high vs. low temperature, and final seed moisture content. This neglect may have caused large decreases in the benefits derived from conditioning.

Small vegetable seeds have been air-dried at 15 to 32°C or at room temperature, usually for extended periods, before they are stored, sown, or planted. A fluidized drying procedure in which RH, air velocity, and temperature were regulated (Niemow et al., 1991) was used recently to dry leek (Allium porrum L.) seeds. Few studies have been conducted on osmoconditioning or matriconditioning large vegetable seeds (e.g., snap bean) and cereals, and even fewer have been conducted on drying after conditioning. Air-drying osmoconditioned soybean [Glycine max (L.) Merr.] seeds at 25°C for 24 h retained, to a large extent, the benefits of conditioning as determined by emergence in a soil mix at a suboptimal temperature (8°C) in a growth chamber, but not in early field plantings (Khan et al., 1980/81; Knypil and Khan, 1981). Sweet corn (Zea mays L.) seeds, matriconditioned with calcined clay and dried in a chamber at 25°C and 45% RH, had a higher germination percentage in a cold medium than nonconditioned seeds (Parera and Cantliffe, 1992a).

To determine initial and final moisture content of the seeds, Grabe’s (1989) air-oven method was used. All seed samples were ground and dried for 2 h at 130°C. The process was modified for seeds with initial moisture content >17% (wet basis). To facilitate grinding, these seeds were predried for 5 to 10 min at 130°C to reduce the moisture content, and, after a 2-h break at room temperature, ground and redried for 2 h at 130°C.

Changes in seed moisture content found during drying in a thin layer were predicted using a modified exponential model (Table 1) (Huizhen and Morey, 1984; Misra and Brooker, 1985) based on the Page equation: MR = exp (–kt), where MR = moisture ratio, k and n = estimated parameters, and t = drying time (min). The model was fitted by Murquardt’s method using SAS’s NLIN procedure (SAS Institute, 1990).

To determine electrical conductivity (EC)
in the seed leachate, nontreated, matriconditioned, and matriconditioned and dried (at 35C, 30% RH, and 1.4 m·s\(^{-1}\)) seeds were rinsed for a few seconds with deionized water.

Twenty-five seeds were soaked in 75 ml deionized, and matriconditioned and dried (at electrolytes leached during soaking were determined by a digital conductivity meter (VWR, Rochester, N.Y.). EC was expressed in microSiemens per centimeter per gram of seeds.

Matriconditioned seeds that were dried to 15% (wet basis) moisture content at 35C, 30% RH, and 0.02 to 1.4 m·s\(^{-1}\) and that performed optimally in a cold germination test (Ptasznik et al., 1992) were used. Eight nontreated, matriconditioned, and matriconditioned and dried seeds per row per plastic box (35 x 26 x 11 cm) in three replications (three boxes) were planted 1 cm deep in a 1 peat : 1 vermiculite mix, and seedling emergence was determined by a digital conductivity meter (VWR, 35C, 30% RH, and 1.4 m·s\(^{-1}\) optimally in a cold germination test (Ptasznik et al., 1992) were used. Eight nontreated, matriconditioned, and matriconditioned and dried seeds were planted in 6-m rows, 75 cm apart, 5 cm deep. The average maximum and minimum temperatures and in early field plantings under suboptimal temperatures.

When matriconditioned snap bean seeds were dried to a final moisture content of 15% (Fig. 4A) and 22% (Fig. 4C), emergence began 1 to 2 days earlier than for the nontreated seeds. The percent emergence of matriconditioned seeds dried to 15% moisture content at 35C and 1.4 m·s\(^{-1}\) was higher than for nontreated seeds (Fig. 4A). Nondried matriconditioned seeds or those dried at 0.02 to 0.7 m·s\(^{-1}\), although showing a trend of increasing emergence, did not differ significantly from the nontreated seeds. Matriconditioned seeds dried to 22% moisture content at 0.02 to 1.4 m·s\(^{-1}\) did not differ significantly in percent emergence from nontreated or nondried matriconditioned seeds (Fig. 4C).

Matriconditioned seeds dried to 15% moisture content at 0.02 to 1.4 m·s\(^{-1}\) produced seedlings with higher fresh and dry weights than the nontreated seeds, while those dried at 1.4 m·s\(^{-1}\) produced higher seedling fresh and dry weights than the nondried matriconditioned seeds or those dried at lower air velocities. A high EC (90.3 µS·cm\(^{-1}\)) similar to that of nontreated seeds was obtained when matriconditioned seeds were dried to 15% moisture content at 0.02 m·s\(^{-1}\). These data suggest that rapid drying to 15% moisture content may retain the benefits of matriconditioning by ensuring greater cellular integrity than slow drying. Drying at all air velocities seems to be less disruptive to the seed when drying progresses only to 22% instead of 15% moisture content, as revealed by the lower electrolyte leakage. However, planting seeds with high moisture content may render them highly susceptible to soil pathogens, particularly under cold, wet conditions (see below).

We previously reported, using a cold germination test, that the benefits of matriconditioning were best retained when the conditioned seeds were dried at 35C, 30% to 40% RH, and 0.7 to 1.4 m·s\(^{-1}\) (Ptasznik et al., 1992). These drying conditions also were effective in the present study, as shown by the fact that rapid drying retained the capacity for improved emergence and biomass production in a peat–vermiculite mix under controlled temperatures and in early field plantings under suboptimal temperatures.

### Table 1. Drying conditions and constant values in the Page equation evaluated by Murquardt’s method.

<table>
<thead>
<tr>
<th>Relative humidity (%)</th>
<th>Velocity (m·s(^{-1}))</th>
<th>Drying Constant</th>
<th>Equilibrium moisture of snap bean seeds (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>0.02</td>
<td>-0.000777</td>
<td>4.80</td>
</tr>
<tr>
<td>40</td>
<td>1.40</td>
<td>0.02</td>
<td>4.80</td>
</tr>
<tr>
<td>60</td>
<td>0.02</td>
<td>-0.000062</td>
<td>9.30</td>
</tr>
<tr>
<td>80</td>
<td>1.40</td>
<td>-0.014675</td>
<td>9.30</td>
</tr>
</tbody>
</table>

Fig. 1. Time course of water absorption by snap bean seeds during matriconditioning.
environment of the peat–vermiculite mix and to possible infestation of the mix with damping-off organisms.

In the 1 May 1992 field planting, matriconditioned and dried matriconditioned seeds had similar emergence percentages (65% to 70%), which were significantly higher than that (53%) of nontreated seeds (Fig. 5A). However, no significant differences were found in plant yield among the various treatments (Fig. 5B). Although matriconditioning snap bean seeds can result in rapid emergence in early field plantings, it sometimes reduces (particularly under wet conditions) the final emergence compared to that of nontreated seeds. A seed treatment with fungicides and gibberellin during matriconditioning greatly improves final emergence (Khan and Ptasznik, 1992; Khan et al., 1992). It would be useful to determine the response of dried matriconditioned seeds to fungicides and hormones.

These data indicate that rapid and controlled drying may be essential for retaining the benefits of snap bean seed matriconditioning and, under the cold, wet conditions found during early plantings, may even augment the benefits of matriconditioning alone. The fact that rapid drying (with RH and air velocity constant) at 35°C retains the benefits of matriconditioning more than slow drying at 25°C (Khan and Ptasznik, 1992; Ptasznik et al., 1992) suggests that it may be necessary to select temperatures ideal for seed conditioning and drying. Effective matriconditioning of snap beans is achieved in 2 days at 15°C and ≈45% RH, and optimal drying after matriconditioning is achieved at 35°C (at 0.7 to 1.4 m·s⁻¹ and 30% to 35% RH) in 5 to 6 h.

Controlled, rapid drying of matriconditioned snap bean seeds to 15% moisture content at a moderately high temperature (35°C), low RH (30% to 35%), and high air velocity (0.7 to 1.4 m·s⁻¹) retains the benefits of matriconditioning, as evidenced by decreased electrolyte leakage and improved seed performance. In some cases, rapidly drying matriconditioned seeds can augment the benefits of matriconditioning. Drying time (fast vs. slow), final seed moisture content (15% vs. 22%), and planting medium influence seed performance and plant yield. Drying matriconditioned seeds to low moisture content should facilitate handling, storage, transport, and planting operations.

**Literature Cited**


Fig. 4. (A) Emergence and (B) fresh and dry shoot weight of matriconditioned snap bean seeds planted, with or without drying, to a final moisture content of 15% (wet basis). (C) Emergence and (D) fresh and dry shoot weight of matriconditioned seeds planted, with or without drying, to a final moisture content of 22%. Shoot weight was determined 16 days after planting. Mean separation of emergence percentages (A and C) and fresh and dry weights (B and D) by analysis of variance and Duncan’s multiple range test (α = 0.05). UNT = nontreated, MC = matriconditioned, MCD = matriconditioned and then dried.

Fig. 5. (A) Emergence and (B) plant yield following 1 May 1992 field planting of matriconditioned and matriconditioned plus dried (final moisture content, 15% (wet basis)) snap bean seeds. Emergence and yield (root, shoot, and pod weight) were determined 30 and 70 days after planting, respectively. Mean separation of emergence percentages and plant yield by analysis of variance and Duncan’s multiple range test (α = 0.05). UNT = nontreated, MC = matriconditioned, MCD = matriconditioned and then dried.