Stand Establishment of Fresh-market Tomatoes Sown at High Temperatures

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Abstract. Primed, pregerminated, or nontreated tomato (Lycopersicon esculentum Mill.) seeds were field-sown with several soil amendments to assess stand establishment at high temperatures. Soil amendments did not consistently improve tomato stand establishment. However, covering seeds with a fine-textured calcined montmorillonite clay (Growsorb) resulted in similar or improved total percent emergence, emergence rate, and seedling shoot dry weight as compared to the soil cover (control) for nontreated, primed, or pregerminated seeds. Plug-mix (a peat-vermiculite medium) or gel-mix, covered over or mixed with nontreated, primed, or pregerminated seeds, did not consistently improve total percent emergence over the soil cover. However, soil amendments generally resulted in faster emergence and more plants with heavier seedling shoot weights than nontreated or pregerminated seeds sown at high temperatures.

Erratic emergence of field-sown tomatoes can occur with high soil temperatures, dry seedbeds, or when heavy rains occur shortly after sowing. These extreme environmental conditions often necessitate resowing of uneconomical high amounts of seed to obtain an acceptable plant stand. Even if adequate plant populations are achieved with field sowing in extreme environmental conditions, variations in plant emergence, growth, and development may subsequently reduce uniform maturity and earliness of fruit yields.

Investigations on plant establishment of direct-seeded tomatoes have focused on enhancing seedling uniformity in northern latitudes at subtropical temperatures. Success with fluid drilling pregerminated seed of other vegetable crops (Currah et al., 1974) encouraged researchers to adapt this technique to improve tomato plant establishment. Bussell and Gray (1976) reported that fluid drilling of pregerminated tomato seed reduced mean emergence time, improved total percent emergence, and reduced variability in emergence time at low temperatures as compared with planting nontreated seeds. Osmotic priming of tomato seeds accelerated seed germination at temperature extremes (Bradford and Murray, 1983; Bussell and Gray, 1976; Ells, 1963; Odell and Cantliffe, 1986). Earlier seedling emergence from primed (Leskovar and Sims, 1987; Wolfe and Sims, 1982) or pregerminated (Gray et al., 1979; Taylor, 1977) seeds has led to earlier fruit harvest. However, Alvarado et al. (1987) reported that the earlier growth from primed tomato seeds did not significantly improve early and total yields, or fruit soluble solids content as compared to nontreated seeds.

Soil amendments, such as gels and anticrusts, have been used to reduce pre-and post-germinative stresses such as soil crust and rapid drying of the seed bed (Ells, 1965; Orzolek, 1982). The objectives of our investigations were to determine if tomato seed priming and pregermination in combination with several soil amendments could improve stand establishment under high field temperatures.

*Standard experimental procedures. 'Floridade' tomato seeds were planted on a fine sandy soil (Plummer Series; loamy, siliceous, thermic Ultic Glossic Paleudult) at the Inst. of Food and Agricultural Science Horticulture Unit, Gainesville, Fla., on nonfumigated raised beds. Beds were 30 cm high, 90 cm wide, and spaced at 1.5-m centers. Soil (2-cm depth) and air (46 cm above the bed surface) temperatures were measured with a recording thermograph for the duration of the experiments, and rainfall was recorded for each of three experiments (Table 1).

Fertilizer was preplant soil-incorporated into the beds at 16.5 N, 9.6 P, and 18.2 K (kg·ha⁻¹). If insufficient rainfall (<1 cm·day⁻¹) occurred, irrigation was applied daily for 1 h by overhead sprinklers at 12 mm·h⁻¹.

Seeds were sown in shallow depressions (2 cm) in the center of each raised bed and then either mixed with or covered by 60 ml of a soil amendment. The same seed lot of ‘Floridade’ was used for each experiment. Five seeds were sown per depression, which were 30 cm apart. Each plot consisted of 10 depressions.

Seedling emergence was counted daily, and emergence rate was calculated as mean days to emergence (MDE) (Gerson and Honma, 1978). A seedling was considered emergent when both cotyledons were above the soil surface and the hypocotyl was no longer hooked. Shoots from 10 selected seedlings per replication were excised at the soil surface 21 days after sowing, dried at 60°C for a minimum of 5 days, and weighed.

A randomized complete block design was used, with each seed and soil amendment treatment combination replicated four times in each experiment. Analysis of variance (ANOVA) was conducted for each measured or calculated variable. Significant main effects were partitioned by a least significant difference (LSD) test at P = 0.05. If a measured trait had a significant soil amendment by seed treatment interaction, then main effect means were ignored and interaction means were separated by an LSD test at P = 0.05.

Pregermination 72 h (Expt. 1). Seed were pregerminated, primed, or nontreated. Seeds were pregerminated (radicles ≈2 mm in length) in the dark on moistened filter papers

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Table 1. Daily mean air and soil temperature and rainfall during each experiment.*

<table>
<thead>
<tr>
<th>Expt.</th>
<th>Sowing date</th>
<th>Temp (°C)</th>
<th>Rainfall</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Air°</td>
<td>Soil°</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Day</td>
<td>Night</td>
</tr>
<tr>
<td>1</td>
<td>13 Sept 1985</td>
<td>31.5</td>
<td>20.4</td>
</tr>
<tr>
<td>2</td>
<td>27 Sept 1986</td>
<td>32.0</td>
<td>13.9</td>
</tr>
<tr>
<td>3</td>
<td>22 July 1987</td>
<td>40.5</td>
<td>23.2</td>
</tr>
</tbody>
</table>

*Measurements were made 10 days after each sowing date.
°Air temperatures were measured 46 cm above the soil surface.
+Soil temperatures were measured at a 2-cm depth.
^Number of days precipitation occurred.
in petri dishes (9 cm in diameter) for 72 h at 25C. Seeds were primed in an aerated solution of 1.5% K$_2$PO$_4$ + 1% KNO$_3$ for 6 days at 25C in the dark and then dried to 6% moisture at 10C and 45% relative humidity (Odell and Cantliffe, 1986).

Soil amendment treatments were plug-mix, a peat-vermiculite potting medium (W.R. Grace Co., Cambridge, Mass.); gel-mix, a 1:1 mixture (v/v) of plug-mix and a 0.75% solution of Liquidel, a hydrophilic starch-acrylate copolymer (Grain Processing, Muscatine, Iowa); and Growsorb as LVM 24/48, a fine-textured, calcined montmorillonite clay (Mid Florida Mining, Lowell, Fla.). A cover of sandy field soil served as the control. Soil amendments were applied as covers over the seeds of each treatment. Pregeminated seeds were sown manually in a 0.55% Liquidel (3 ml/five seeds) before being covered by the soil amendments and irrigated.

**Pregermination 60 h (Expt. 2).** Seeds were primed, pregerminated, or nontreated. Priming and pregermination of seeds were identical to procedures described in Expt. 1. Imbibition time for pregerminated seeds (50% of seeds with visible radicles) was 60 h, since 72 h reduced emergence in Expt. 1. Soil amendments were as described in Expt. 1 with the addition of Viterra II gel-mix, a 1:1 mixture (v/v) of plug-mix and a 0.55% solution of Viterra II gel, a hydrophilic polyacrylate polymer (Nepera, Harriman, N.Y.). Soil (control) or soil amendments were applied over the seeds. Seeds were also mixed with Liquidel-gel mix and Viterra II gel mix before field sowing. Seedling shoot dry weights were not measured due to severe damping-off and insect damage that occurred during the 3rd week after sowing.

**Pregermination 48 h (Expt. 3).** Seed treatments were nontreated, primed, or moisturized. Primed seeds were prepared as described in Expt. 1. Imbibition time for moisturized seeds (minimal seeds with visible radicles) was reduced to 48 h in an attempt to further improve emergence.

Soil amendments were plug-mix; Viterra NT/L gel-mix (a finer particle preparation of Viterra II); plug-mix plus dry gel (5.5 g Viterra NT/L); plug-mix moistened with 70 ml of water; Growsorb; and gel-mix plus Growsorb as LVM 24/48. Seeds were sown in 30-ml aliquots of Viterra gel-mix, then covered with 30 ml Growsorb. A cover of field soil served as the control.

Growsorb amendments and soil were applied as covers over the top of each seed treatment. Due to reduced imbibition time (48 vs. 60 or 72 h), moisturized seed treatment had few seeds with protruding radicles. Therefore, incorporating the moisturized seeds in a protective gel was not necessary before covering them with soil or Growsorb. All other soil amendments were applied with the seeds previously incorporated.

Daily soil temperatures averaged higher than 40C during the 10 days following sowing in Expt. 1 (Table 1). Planting germinated seeds with exposed radicles (pregeminated seed treatment) into a hot soil drastically reduced total percent emergence as compared...
with nontreated or primed seeds (Table 2). Seed treatment \times soil amendment interactions were significant for MDE and total percent emergence (Table 2). Nontreated or primed seeds covered with soil or Growsorb had similar total percent emergence (Table 2). However, total percent emergence was significantly lower if primed seeds were covered with plug-mix or Liquagel gel-mix as compared with soil or Growsorb. MDE was similar for all soil amendments for primed seeds. However, nontreated seeds covered with Liquagel gel-mix or Growsorb exhibited reduced MDE as compared to the soil cover.

Since percent emergence from prergerminated seeds was low, a sufficient number of plants could not be sampled for seedling dry weight measurements. However, primed seeds had produced heavier seedling shoots than nontreated seeds by 21 days after sowing (Table 2). Seeds covered with plug-mix produced heavier seedling shoots as compared with the other soil amendment treatments, except for the soil cover.

Seed treatment \times soil amendment interactions were significant for MDE and total percent emergence in Expt. 2 (Table 3). Priming of seeds resulted in a higher total percent emergence than their prergermination, except when seeds were mixed in gel-mix. Soil amendments did not improve total percent emergence for nontreated or primed seeds as compared with the soil cover. However, each soil amendment, except for plug-mix and Liquagel gel-mix covers, increased total percent emergence from prergerminated seeds relative to the soil cover. Primed seeds emerged faster than nontreated seeds, regardless of soil amendment. Each soil amendment, except for plug-mix cover of nontreated seeds and Growsorb cover for each seed treatment, resulted in a faster emergence than the soil cover. Total percent emergence or MDE for nontreated seeds were similar between mixed or cover treatments of Liquagel gel-mix or Viterra II gel-mix.

Soil amendment \times seed treatment interaction was significant for MDE in Expt. 3 (Table 4). Primed seeds emerged more rapidly than nontreated seeds, regardless of soil amendment, and more rapidly than prergerminated seeds with soil or Growsorb covers. Each soil amendment resulted in faster emergence than the soil cover, regardless of seed treatment. Therefore, the soil amendment \times seed treatment interaction was attributed to differential MDE responses within soil amendment treatments, other than the soil cover. Shoot weights were significantly higher for seedlings from primed seeds than from nontreated or prergerminated seeds (Table 4). Each soil amendment improved seedling shoot weight as compared with the soil cover.

Tomato seeds with exposed radicles may be more sensitive to high soil temperatures, regardless of soil amendment, than nontreated or primed seeds without exposed radicles. Similarly, fluid drilling of prergerminated seeds or gel treatments applied in hot, dry conditions resulted in poorer plant establishment than under cool, moist conditions for several crucifers (Kahn and Motes, 1988, 1989; Perkins-Weazie and Cantliffe, 1989). Our data indicate that priming of tomato seeds generally improved stand establishment under high temperature conditions relative to prergermination or no seed treatment. Soil amendments did not consistently improve stand establishment of tomatoes under high-temperature conditions. However, total percent emergence was similar or improved with Growsorb soil amendment, and faster emergence generally occurred for most soil amendments as compared with the soil cover, regardless of seed treatment. These results are useful to tomato producers who must obtain plant emergence under high temperatures, as found in Florida, in that soil amendments, such as Growsorb, will overcome problems with soil compaction, poor aeration, and water logging that commonly occur in summer and fall in Florida's sandy soils. The use of primed seed will overcome thermo-inhibition of the tomato seed; thus, the combination of amendment and priming will ensure more rapid, uniform stands under these stressful conditions.

### Literature Cited


