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IMPROVING STAND ESTABLISHMENT OF DIRECT SEEDED VEGETABLES IN FLORIDA

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Abstract. **The emergence of direct seeded vegetables can be reduced by numerous environmental and physical stresses which commonly occur at the time of sowing in Florida. Temperature extremes, heavy rainfall, drought, and soil compaction can greatly alter total plant stands and seedling uniformity. A number of seed priming treatments improved germination and emergence of cabbage (*Brassica oleracea* L.), carrot (*Daucus carota* L.), celery (*Apium graveolens* L.), tomato (*Lycopersicon esculentum* Mill.), pepper (*Capsicum annuum* L.), and lettuce (*Lactuca sativa* L.). An additional improvement in stand uniformity for a number of crops was obtained when seeds were sown with soil amendments. Use of the gel-mix (peat:vermiculite:gel combination) and/or calcined clay amendments (GrowSorb) greatly improved emergence and plant uniformity in pepper, tomato, cabbage, and lettuce sown under temperature stress.**

Seeds for the Florida winter vegetable industry are sown over an extended season, which generally encompasses environmental extremes of temperatures and moisture regimes. Planting of the major vegetable species begins in Aug. and/or early Sept. under excessively high temperatures and, in many cases, continues through or begins again under the low temperature extremes of Jan. and Feb. Plant establishment of most crops becomes limited by high temperatures (above 30°C) resulting in poor stands. Low temperatures, on the other hand, reduce emergence rate, thereby creating uneven plant stands and subjecting the emerging seedlings to soil-borne pathogens for an extended period of time.

Recent technology has led to improved germination and emergence of seedlings after treating the seed by a process called priming (2). The priming treatment consists of imbibing seeds in an osmotic solution such as polyethylene glycol (PEG) or salt, at a concentration that allows the seed to imbibe water and advance through the first stages of germination but which does not permit radicle protrusion through the seed coat. Seed priming has been reported to increase germination rate, total germination, and seedling uniformity, especially under unfavorable environmental conditions (1, 3, 4, 5, 10, 11). 'Slow' and 'fast' germinating seeds of a single lot are brought to the same stage of germination readiness after priming. This is of utmost importance to achieve plant stand uniformity. A major advantage of priming is that seeds can be primed (germination initiated), redried to their original moisture content, and then stored or sown using conventional planting equipment.

Seed with low germination percentage or of generally poor quality cannot be improved by priming (13). Only the highest quality seed gives positive results to seed priming under field stress conditions. Several factors must be considered when priming seed including the osmoticum source and concentration, duration of the soak, temperature, aeration technique, light requirements, redrying procedure, and seed quality (2).

The soil environment can play a key role in regulating emergence, especially under conditions of excessive moisture or high temperature. Soil crusting can occur on Florida's sandy soils and is promoted by heavy rainfall, high radiant energy, and the level of organic material in the soil. Frequent wetting and drying can initiate excessive soil crusting, thus limiting plant stands and uniformity (14, 18, 19). The work reported here, summarizes research on a number of vegetable crops to improve field emergence via seed priming and/or the use of soil amendments.

Materials and Methods

Details for specific information materials, methods, and procedures, including cultivar names, planting dates and priming treatments are referenced directly on the Tables. In order to successfully prime seeds of the various species, several factors were considered including nature of the osmoticum, water potential, duration of the soak, temperature and requirement for high quality seeds. All seeds were primed in the dark in aerated solutions. Typically, 1 g of seeds were placed in a 50 ml test tube along with 30 ml of the priming solution which was aerated through a glass tube connected to an aquarium pump. At the completion of the priming process the seeds were rinsed twice with distilled water to remove the residual osmoticum. Surface water was removed by vacuum filtration, then the seeds were dried at 5°C and 30% relative humidity to their original moisture content. The 5°C-30% relative humidity constituted the long term seed storage conditions used in some studies.

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Laboratory germination tests were conducted in the dark in incubators maintained at constant temperatures. Generally, 4 replicates of each treatment were germinated in 9 cm Petri dishes, each containing of 25 seeds placed on 1 sheet of Whatman #3 and 1 sheet of Whatman #1 filter paper moistened with 5 ml of distilled water. A seed was considered germinated when the radicle visibly protruded from the testa. Germination tests ran for a minimum of 14 days. Total percentage germination and mean days to germination (MDG) or emergence (MDE) were calculated by the method of Gerson and Honma (7).

Details of field experiments are referenced in the Tables. Plantings of all crops were made by hand, and dry weights were recorded at specified times by randomly cutting at least 10 seedlings per plot then drying at 70°C for 72 hrs. in a forced air oven. The specific seed treatments are outlined in the Tables. The soil amendments consisted of 1) Plug mix, a peat-vermiculite mix (W. R. Grace, Inc.); 2) gel mix, consisting of a gel such as Liquagel (starch-acrylamide-acrylate product of Grain Processing), or Laponite (a magnesium silicate product of Laporte Industries) which was added to water at a certain concentration and then mixed at an equal volume (liquid:solid) with Plug mix; 3) GrowSorb (a calcined attapulgite clay product of Mid Florida Mining); and/or 4) a fine sand field soil.

Generally, each treatment in the field was replicated 4 times with 100 seeds per replicate. Soil or one of the amendments was applied by hand at a rate of 30 ml per seed drop for lettuce and tomato, 60 ml for pepper or 260 ml/m of row in a band placement on cabbage. The lettuce and cabbage were irrigated immediately after planting and thereafter with over-head irrigation, whereas the pepper and tomato were irrigated via sub-surface methods. Polyethylene mulch was used on all crops grown in the field except cabbage.

Results and Discussion

Seed priming at 15°C in the dark significantly increased both the percentage and rate of germination of carrots at all temperatures tested (Table 1). The overall effect of priming on germination was most apparent at 35°C where only 11% of the nontreated seeds germinated compared to 74% of the primed seeds. Uniformity and rate of germination of carrot seeds were increased 2-fold by priming.

The germination of the seeds of many species is adversely affected by high temperatures. At 35°C, a temperature common to summer-early fall plantings in the greenhouse or field in Florida, both the rate of and total germination of tomato seeds were severely inhibited (Table 2). Priming the seeds in different osmotica equally improved total germination; however, uniformity and germination rate were best when the seeds were primed in a solution containing the salts of K_3PO_4 and KNO_3.

The duration and temperature of the priming treatment greatly affected the subsequent germination of lettuce seed at 35°C (Table 3). A 12 hr soak at 15°C was more effective than a 6 hr soak or priming at 5° or 25°C. Soak duration was extremely important to the effectiveness of priming pepper seed when the seeds were germinated at 15°C (Table 4). Nontreated pepper seed exhibited a very slow germination rate at this temperature but the rate was increased 2- to 3-fold after priming. Although a soak duration of 6 days led to the greatest increase in germination rate, a large number of abnormal seedlings were observed. This was most likely the result of bringing the priming process too far thus allowing radicle development. Upon drying, the radicle tip on pepper dies (4). For this reason, a 4-day prime duration most effectively promoted germination rate without reducing final stand.

Table 1. Effect of seed priming on germination of 'Orlando Gold' carrots averaged over 3 seed lots at 15, 25, or 35°C in the laboratory (6).[z]

Treatment	Temperature °C		
	15	25	35
	Germination (%)		
Not treated	81	71	11
Primed (–10 bars PEG)	90	81	74
	*[y]	*	*
	Mean days to germination		
Not treated	6.3	5.3	7.3
Primed (–10 bars PEG)	5.3	3.7	4.5
	*	*	*

[z]Seeds were primed at 15°C in the dark for 14 days.
[y]Mean separation by F test, * significant at the 5% level.

Table 2. Effect of osmoticum on the total percentage and mean days to germination (MDG) of 'FloraDade' tomatoes germinated at 35°C in the laboratory (9).

Priming osmoticum treatment	Germination (%)	MDG
Not treated	17 b[z]	6.4 a
1.5% K_3PO_4 + 1% KNO_3[y]	96 a	1.7 d
2.4% KNO_3	93 a	3.3 bc
32.5% PEG 6000	98 a	3.8 b

[z]Mean separation in columns by Duncan's multiple range test, 5% level.
[y]Seeds were primed for 6 days at 25°C.

Table 3. The effect of priming at different temperatures and soak durations on percent germination of 'Minetto' lettuce seeds at 35°C in the laboratory (8).[z]

Prime temperature °C	Soak duration (hr)	
	6	12
	Germination (%)	
5	18 b[y]	53 b
15	44 a	72 a
25	48 a	20 c

[z]Seeds were primed in the dark in 1% K_3PO_4. Seeds which were not primed did not germinate.
[y]Mean separation in columns by Duncan's multiple range test, 5% level.

Table 4. Effect of soak duration during priming at 15°C in PEG at –6 bars on 'Early Calwonder' pepper seed germination at 15°C in the laboratory (4).

Prime soak duration (days)	Germination		
	Total (%)	Abnormal (%)	Rate (MDG)
0	83 a[z]	3 c	8.0 a
4	87 a	0 c	3.8 b
5	81 a	14 b	2.7 c
6	85 a	59 a	1.6 d

[z]Mean separation in columns by Duncan's multiple range test, 5% level.

Table 5. Effect of priming on germination in the laboratory at 25°C of 'Earlybelle' and '683-K' celery.

Treatment	Cultivar: Earlybelle	683-K
	Germination (%)	
Not treated	0 b[z]	0 b
Primed (PEG)[y]	0 b	26 ab
PEG + $GA_{4/7}$ + BA	22 a	82 a

[z]Mean separation in columns by Duncan's multiple range test, 5% level.
[y]Seeds were primed at −12.5 bars at 15°C for 14 days.

Table 7. Main effects of seed cover on percent desired stand at harvest, mean days to emergence (MDE), and yield of 'Rio Verde' cabbage sown in the field on 2 dates in Gainesville (12).

	Planting date					
	2 Sept.	14 Oct.	2 Sept.	14 Oct.	2 Sept.	14 Oct.
Seed cover	desired stand (%)		MDE		Yield (Mt/ha)	
Soil	36 c[z]	93 a	5.7 b	5.5 b	21.6 c	54.2 a
Plug-mix	57 b	93 a	6.2 b	4.9 a	35.6 b	42.2 a
GrowSorb	82 a	93 a	5.2 a	5.0 a	55.1 a	50.2 a

[z]Mean separation in columns by Duncan's multiple range test, 5% level.

Celery seed would not germinate at 25°C unless primed (Table 5). This was cultivar dependent because seeds of 'Earlybelle' did not germinate after priming unless the growth hormones gibberellic acid 4+7 (GA 4+7) and benzladenine (BA) were added during priming. Germination was 22% after the hormone treatment. The addition of the hormones to the priming solution improved germination of cultivar 683-K from 26% to 82%. The '683-K' seeds were determined to be of much higher quality than 'Earlybelle' (Tanne, unpublished).

Under field conditions the method of irrigation affected final stand of cabbage. When overhead irrigation was used, emergence of primed seed was better than with seeds neither treated nor germinated before planting, and equaled emergence of seeds sown with Plug mix (Table 6). Only Plug mix improved emergence of cabbage irrigated with sub-surface techniques. Thus, seed treatments cannot substitute for dry soil surface conditions. Soil covers such as Plug mix can improve emergence under unfavorable conditions when coupled with adequate overhead irrigation. Emergence of cabbage in an early Sept. planting was improved by the use of Plug mix and more than doubled when a calcine clay product GrowSorb was used as a soil amendment (Table 7). Emergence rate was improved by GrowSorb compared to Plug mix or soil as a seed cover. Yields were almost tripled by the same soil cover on this planting date. Plant stands in a mid-Oct. planting, under more favorable conditions, were not improved by any of the seed covers. Besides improving total and rate of emergence of peppers, a gel mix formulation (Plug mix + a gel additive) improved seedling growth over Plug mix alone (Table 8). This may have been due to improved moisture holding abilities of the mix and/or additional nutrients from the gel (16).

Table 6. Effect of seed treatment and irrigation method on 'King Cole' cabbage seedling emergence at Sanford, Florida (20).

	Method of irrigation			
	Overhead		Sub-surface	
Treatment	Emergence (%)	MDE	Emergence (%)	MDE
Not treated	32 c[z]	7.8 a	7 b	7.0 a
Plug-mix	52 ab	7.9 a	35 a	7.1 a
Primed[y] (−8 bars PEG)	56 a	6.8 a	11 b	6.3 a
Primed (−10 bars PEG)	42 bc	6.9 a	10 b	6.3 a
Pregerminated	30 c	6.9 a	6 b	6.0 a

[z]Mean separation in columns by Duncan's multiple range test, 5% level.
[y]Seeds were primed at 15°C for 14 days.

The soil amendments LVM GrowSorb or Plug mix improved emergence more than did priming of lettuce seed sown on a sandy soil and irrigated by overhead sprinklers (Table 9). Another GrowSorb product, RVM, absorbed water and solidified over the seed thus reducing germination. The latter product was a clay, gas fired at lower temperature than the LVM product. The RVM was developed to absorb water. Seedling growth of lettuce was improved more by soil amendments than a soil cover, while seed priming generally improved seedling growth rates regardless of the type of seed cover or amendment used (Table 10).

Total emergence of 'Floradade' tomatoes sown under field conditions was improved by GrowSorb or by priming the seed (Table 11). Emergence rate was improved by seed priming. Generally, the combination of seed priming with GrowSorb as a soil amendment covering led to the most rapid and uniform emergence of tomatoes.

The use of primed seed improved germination percentage, uniformity, and rate under both laboratory and field conditions for a number of different vegetable species. Priming allows 'slow' and 'fast' germinating seeds of a single lot to attain the same stage of germination readiness. The priming process was especially useful in promoting germination under conditions of environmental stress, especially high temperature. Regardless of the conditions at the time of sowing, seed priming always increased the rate of germination or field emergence.

Various factors affected the success of the priming process. The use of salt as an osmoticum may add some nutritional value to the treatment; however, extended soaking

Table 8. Effect of planting method on stand establishment (% emergence and mean days to emergence—MDE) and seedling growth (dry wt) 45 days from sowing of peppers sown at Boynton Beach on 25 Sept. (15, 16).

Treatment	Emergence (%)	MDE	Dry wt. (mg/plant)
1. Liqua-gel mix (0.75%)	92	5.0	2243
2. Liqua-gel mix (1.25%)	75	5.8	1651
3. Laponite gel mix (1.25%)	90	7.5	1523
4. Plug mix	93	5.1	1276
5. Not germinated, plug mix cover	69	8.8	816
Orthogonal contrasts			
1234 vs 5	*	*	*
123 vs 4	*	*	*
12 vs 3	NS	*	NS
1 vs 2	*	*	NS

NS is non significant or * significant at the 5% level.

Table 9. Effects of seed treatment and soil amendments on total *emergence of* 'Green Lakes' lettuce sown 15 March in Gainesville (17).

Soil amendment	Seed treatment	
	Not treated	Primed[z]
	Emergence (%)	
Soil	37 b[y]	43 c
GrowSorb LVM(f)[x]	84 a	71 b
GrowSorb LVM(c)	87 a	92 a
GrowSorb RVM(c)	32 b	42 c
Plug mix	87 a	87 a

zPrimed at 15°C for 22 hr in 1% K_3PO_4 in the dark.
yMean separation in columns by Duncan's multiple range test, 5% level.
xf = fine grade, c = coarse grade. LVM = clay fired at high temperature; RVM = clay fired at low temperature.

in the salt solution can damage the germinating seed. The major advantage of PEG is that it is chemically inert and does not have an adverse effect on seed and seedling growth. Radicle emergence during the soak treatment may best be prevented by priming at temperatures below the optimum range for germination of the species. Generally, temperatures of 5° to 20°C were best, with 15°C being established as a suitable prime-temperature for most of the seeds. High temperature during the soak was detrimental to the seed. The duration of the soak was dependent on the species being treated, soak temperature, osmotic potential and the type of aeration. Generally the shorter the duration the less problems with pathogens and premature radicle emergence. Only high quality seed (high percentage germination, high vigor, no pathogens) should be used as evidenced by the experiment with celery. Seed priming cannot bring dead seeds back to life.

Soil conditions in the field have a profound effect on emergence. By substituting an amendment for the native soil covering, the uniformity and total emergence of several crops were improved. The use of a soil amendment with seed priming completely circumvented many problems with stand establishment.

Table 10. Effect of seed treatment and soil amendment on seedling growth as dry weight of 'Green Lakes' lettuce sown on 15 March in Gainesville (17).

Soil amendment	Seed treatment	
	Not treated	Primed[z]
	Dry wt/seedling (mg)	
Soil	9.0 c[y]	11.5 c
GrowSorb LVM(f)[z]	23.3 a	20.5 ab
GrowSorb LVM(c)	23.0 a	26.3 a
GrowSorb RVM(c)	12.5 bc	16.8 bc
Plug mix	16.8 ab	22.3 ab

zSee table 9.
yMean separation in columns by Duncan's multiple range test, 5% level.

Table 11. Effect of seed treatments and soil amendments on percent total emergence and rate of emergence as mean days to emergence (MDE) of 'Floradade' tomatoes sown on 7 Sept. at Bonita Springs (9).

Soil amendment	Seed treatment			
	Not treated		Primed[z]	
	Emergence (%)	MDE	Emergence (%)	MDE
Soil	74 b[y]	6.8 a	92 a	4.8 a
Plug mix	72 b	5.5 b	75 b	3.7 b
Gel mix	70 b	5.4 b	77 b	3.5 b
GrowSorb LVM(f)	89 a	6.6 a	90 a	7.9 a

zPrimed at 25°C for 6 days in the dark in 1.5% K_3PO_4 + 1% KNO_3.
yMean separation in columns by Duncan's multiple range test, 5% level.

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