Water Requirement for Maximum Germination and Emergence of Sugarbeet Seeds[1]

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Sensitivity of sugarbeet seeds[3] to excess moisture during germination, as revealed by lower germination percentages, has been observed by personnel of many seed-testing laboratories. This sensitivity has been demonstrated in the liquid-contact method of germination for seeds of individual plants within a cultivar and for different cultivars.[4] Emergence of sugarbeet seedlings from fine quartz sand at 3, 5, or 7½% moisture did not differ significantly (2)[5].

In repetitive tests where we tried to develop a simple and reliable emergence test, inconsistent emergence of certain seedlots led us to a critical reexamination of the quantity of water needed for maximum germination on blotters and emergence from gravel or sand. Two commercial seedlots, one hypersensitive and the other relatively insensitive to moisture levels, were used in test systems to determine the effect of moisture on germination and emergence. We report differential germination and emergence responses of these two seedlots to small increments of water and relate the germination percentages to the moisture content of the seeds.

Methods and Materials

Initially, 80 samples of processed monogerm sugarbeet seeds,[6] grown in commercial fields in Oregon, were evaluated by blotter germination and emergence from gravel. Four 50-seed replications of each seedlot were germinated on a double layer of moist blotters in a germinator at 70°F. Germination percentages, uncorrected for non-viable seeds, were recorded at 10 days.

Emergence tests were conducted in plastic chambers (10 × 14 × 3.7 in.) covered with a lid. A ½-in. layer of either moistened gravel or sand was spread across the bottom of the container. Seventy-two seeds

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[3]Hereafter seed(s) may be used as a synonym for either the dried fruit or the true seed within the fruit.

[4]Unpublished data of F. W. Snyder.

[5]Numbers in parentheses refer to literature cited.

[6]Samples were supplied by Farmers and Manufacturers Beet Sugar Association, Saginaw, Michigan and the Great Western Sugar Company, Longmont, Colorado.

were placed in the six rows on this layer and then covered to a specified depth with more moistened material. Final emergences were recorded after 12 days.

Gravel-emergence test

A mixture of gravel, sized 2 to 5 mm, was immersed in tap water, drained until water dripped slowly, and immediately used. Eight similarly moistened samples of gravel averaged 4.1% moisture and ranged between 3.7 and 4.6%. Seeds were covered with 1 in. of gravel.

Sand emergence test

Four 1-1 kilogram samples of fine quartz sand (1 to 0.1 mm) were carefully mixed by hand to moisture contents of 4 or 7½%. Seeds were covered with 1½ in. of sand. Both sand and gravel were autoclaved before use to reduce microbial populations.

For most emergence tests, two different seedlots were planted in alternate rows of the container and in three containers (replications), thus totaling 108 seeds per seedlot for a test. In sand emergence test no. 3 (Table 4), the four treatments (2 seedlots × 2 fruit moistures) occurred as six replications, totaling 108 seeds.

Four seedlots (7½-8½/64 in. seed size), designated A, B, C, and D, of a single cultivar grown in different fields in Oregon were selected for field emergence tests in the spring of 1971. Field emergence data, six replications per seedlot, were obtained at five locations in Ohio and one in Michigan.

Seedlot A (relatively insensitive to the quantity of water available during germination and emergence) and D (hypersensitive to water) were used in relating moisture content to germination and emergence. A range of moistures was obtained by immersing samples (approx. 1.1 g) of air-dry seeds in water for given times. Excess water was blotted off before weighing them to determine the percentage moisture absorbed. Some of the weighed samples were immediately placed in plastic envelopes, which were sealed and placed in a germinator for 10 days. Total loss in weight of the plastic envelope and contents during the 10-day period approximated 0.04 g where no germination occurred and probably was the water loss during the 10 days. The percentage germination was related to the percentage moisture of the seeds when placed in the plastic envelopes. Moisture contents were calculated on the air-dry weights of the seeds and were averages for the group of seeds.

Standard deviations were calculated for all replicated data, and Duncan's multiple range test was used to indicate significance differences in germination and emergence of seeds planted dry and those soaked before planting.

Results

In the initial evaluation of the 80 samples of seed, germination ranged from 77 to 99% and gravel emergence from 39 to 95%. High germination percentages did not always correlate with high emergence from gravel; for example, seedlots that germinated between 96 and 99% ranged from 47 to 95% in emergence.

The four seedlots selected for field emergence differed in germination (79 to 99%) and in emergence (from 46 to 95%) (Table 1). Average emergence for the six locations ranged between a low of 41% for seedlot D and a high of 52% for A, and correlated more closely with blotter germination than with gravel emergence.

In repetitive gravel-emergence testing, seedlots A and B emerged rather consistently, but C and D were inconsistent (Table 1). In test no. 12, Table 1, A and D had been placed in alternate rows in the same containers. Results from seedlot A were consistent with prior results, but D had considerably greater emergence than in previous tests. We suspected and tested the hypothesis that small fluctuations in gravel moisture might be causing the inconsistent response of seedlot D. When we immersed seeds of D in water for 1 hour, blotted off the excess water, and planted them in the same containers as dry seeds, emergence from wet seeds was less than half that from the dry ones (test no. 1, Table 2). The data for test no. 2, in Table 2 suggest that the gravel actually was relatively wetter than in test no. 1. In test no. 3, where differences in gravel moisture were established, the greater sensitivity of seedlot D to moisture as compared to that of A is clearly

Table 1.—Repetitive tests for germination and emergence of four seedlots of a commercial sugarbeet cultivar.

Seedlot code	Gravel emergence		Blotter germination	
	Test no.	% S.D.	Test no.	% S.D.
A	5*	95 ± 2.4	3*	98.5 ± 0.9
	11	93 ± 0.9	5	98 ± 1.4
	12	91 ± 1.4		
B	6*	78 ± 4.5	2*	96 ± 1.4
	7*	76 ± 13.1	4	99 ± 1.0
	9	72 ± 6.9		
	13	70 ± 8.2		
C	4*	51 ± 7.4	3*	95 ± 4.1
	10	62 ± 5.5		
	13	44 ± 10.2		
D	1*	43 ± 4.0	1*	79 ± 4.6
	2*	47 ± 3.0	5	81 ± 3.3
	3*	48 ± 14.6		
	8	49 ± 5.7		
	11	58 ± 11.1		
	12	70 ± 4.6		

*Data available when the four seedlots were selected for field emergence testing in 1971.

Table 2.—Effect of seed treatment and gravel moisture on emergence of sugarbeet seedlings from gravel.

Test no.	Seed treatment†	Gravel moisture	Emergence[1] Seedlot A		Emergence[1] Seedlot D	
			%	S.D.	%	S.D.
1*	Nonsoaked, planted dry	Regular			67	± 2.1
	Soaked , planted wet	Regular			31	± 9.0
2	Nonsoaked, planted dry	Regular	a89	± 0.0	b46	± 7.3
	Soaked , planted wet	Regular	a74	± 3.5	b31	± 9.1
3	Nonsoaked, planted dry	Moist	a 87	± 4.7	b68	± 7.9
	Soaked , planted wet	Very wet	ab81	± 5.7	c35	± 6.9

†Soaked = immersed in water 1 hr, blotted.
[1] Means within a test having unlike letters differ significantly at the 5% level, according to Duncan's multiple range test.
*Only 2 replications.

shown. In three subsequent gravel-emergence tests, evaporating moisture from the gravel by removing the lids periodically during emergence increased the emergence of seedlot D, as compared with no drying in a control container.

The sensitivity of seedlots A and D to water during blotter germination is shown in Table 3. When seeds of A and D were placed side by side on blotters and the blotters were maintained at three different moisture levels, A germinated from 91 to 98.5% and D from 67 to 92%. We found that the amount of moisture regularly used for blotter germinations in our laboratory actually suppressed germination of D (79 and 81%) as compared to germination on a "rather dry" blotter (88 and 92%) (Table 3).

Whenever seeds of seedlots A and D absorbed moisture under identical conditions, D always absorbed more water and absorbed it more rapidly than A (Fig. 1). In 30 hours on blotters, A absorbed 30.8 ± 0.7% on a "rather dry" blotter and 37.2 ± 1.1% on a "very wet" one, while under these same conditions D absorbed 33.7 ± 1.5 and 46.9 ± 2.4%, respectively. Blotter moisture in germination test no. 6, Table 3 closely approximated the moisture levels in this absorption test.

Table 3.—Effect of seed treatment and blotter moisture on 10-day germination of sugarbeet seeds.

Test no.	Seed treatment	Blotter moisture	Germination[1] Seedlot A		Germination[1] Seedlot D	
			%	S.D.	%	S.D.
1	Nonsoaked, placed dry	Regular			79	± 4.6
3	Nonsoaked, placed dry	Regular	98.5	± 0.9		
5	Nonsoaked, placed dry	Regular	98	± 1.4	81	± 3.3
6-A	Nonsoaked, placed dry	Rather dry	a97	± 2.1	b88	± 1.8
	Soaked , placed wet	Rather dry	a97	± 1.3	ab92	± 5.8
6-B	Nonsoaked, placed dry	Very wet	a95	± 4.1	b78	± 7.6
	Soaked , placed wet	Very wet	a91	± 4.7	b67	± 7.2

[1]Means within a test having unlike letters differ significantly at the 5% level, according to Duncan's multiple range test.

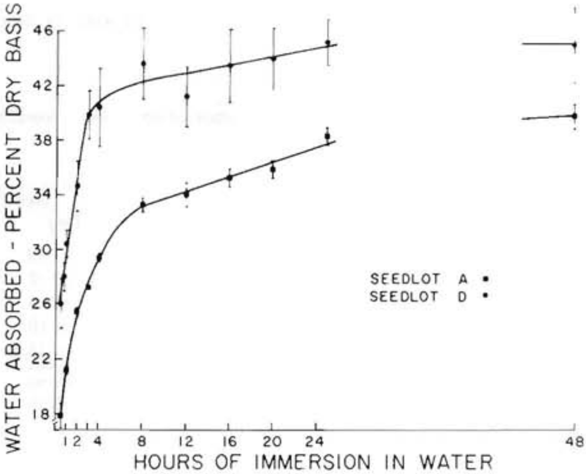

Figure 1.—Relation of time of immersion in water to water absorbed by seeds of two seedlots of a sugarbeet cultivar.

The germination percentages obtained in the plastic envelopes are related to fruit-moisture percentages in Figure 2. Germination varied markedly with very small differences in absorbed moisture, particularly for the marginally deficient levels of moisture. Seedlot A required a lesser percentage of moisture than D to attain high germination.

Emergence tests through 1 in. of sand demonstrated that soaking seeds of seedlot D for 1 hour depressed emergence from sand at 5% moisture, but not from sand at 3%, and that seeds planted dry germinated similarly at both moisture levels. When seeds of seedlot A were hydrated to 34.7% (immersion in water for 18½ hr) and those of D to 32.0% (2¼ hr immersion) before planting in sand at 4% moisture, emergence was reduced significantly for both seedlots as compared

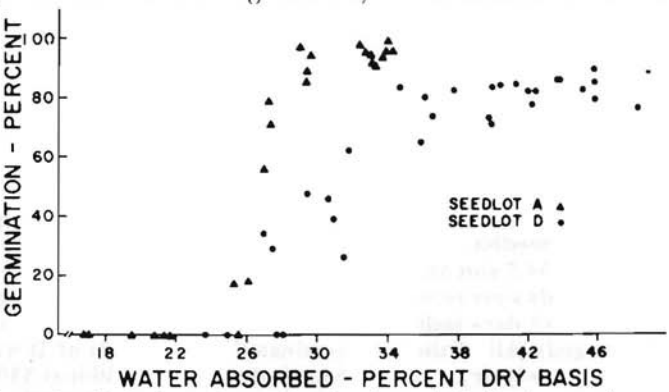

Figure 2.—Relation of germination in sealed plastic envelopes to water absorbed by fruits of two seedlots of a sugarbeet cultivar.

with emergence from air-dry seeds. The effect on D was greater, however (Table 4, test no. 3 and Fig. 3).

Table 4.—Effect of moisture levels on emergence of sugarbeet seedlings through 1½ in. of sand.

Test no.	Sand moisture	Emergence[1]			
		Seedlot A		Seedlot D	
		Dry	Wet	Dry	Wet
		% S.D.	% S.D.	% S.D.	% S.D.
1	4%	89 ± 3.0		71 ± 7.0	
2	4%	a91 ± 4.7		ab79 ± 3.4	
	7½%	a92 ± 2.2		b68 ± 10.7	
3	4%	a91 ± 7.8	b75 ± 7.2	b72 ± 15.2	c44 ± 9.0

[1]Dry = fruits planted dry; Wet = fruits planted wet. See text for details. Means within a test having unlike letters differ significantly at the 5% level, according to Duncan's multiple range test.

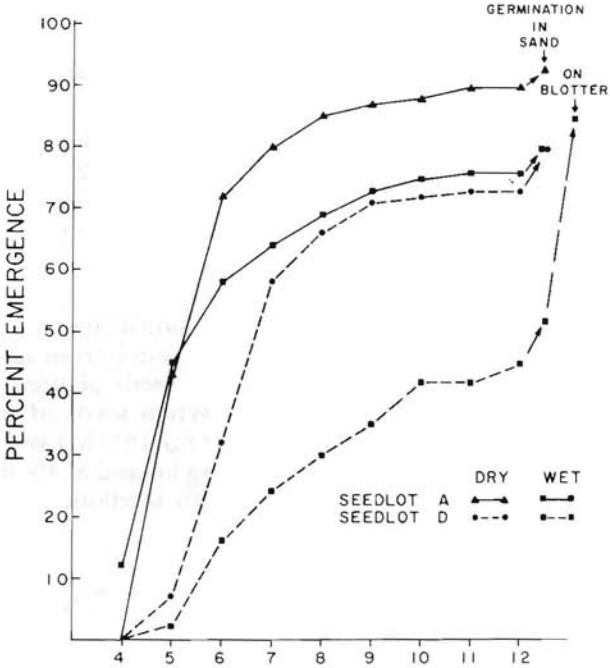

Figure 3.—Accumulated emergence from sand (1½-in. depth, 4% moisture) of two seedlots of a sugarbeet cultivar when seeds were planted air-dry or "wet" (34.7 and 32.0% moisture for A and D "wet," respectively). At 12 days all seeds were removed from the sand to see if they had germinated. Points after 12 days indicate total seeds germinated in sand (emerged and non-emerged). All of the nongerminated "wet" seeds of D were then placed on a relatively dry blotter, which induced an additional 33% to germinate. The last point indicates a total germination of 85% (45% emerged, 7% germinated in sand, and 33% on blotter).

Discussion

A number of the seedlots initially evaluated by gravel emergence have since been reevaluated for emergence from sand at 4% moisture. About half of them had appreciably lower emergence from gravel than from sand at 4% moisture, thus suggesting that sensitivity of sugarbeet seeds to available moisture may be more common and more significant than recognized heretofore.

The fortuitous accession of a sugarbeet seedlot that is hypersensitive in its germination and emergence response to available water has aided in clarifying a number of points. To obtain reliable germination and emergence data, we must control the quantity of water available to the seed much more rigidly than was heretofore believed necessary. Data for seedlot D clearly indicate that "regular" blotter moisture may depress germination. Guidelines for regulating blotter moisture for germination have been used in Canada for some years.[7] The variation in moisture adhering to the gravel (3.7 to 4.6% water based on dry weight of gravel) seems largely responsible for the large variations in emergence of seedlot D. This means that an increase of no more than 0.9 g of water on the surface of 100 g of gravel was sufficient to depress emergence of seedlot D significantly. Thus, the major advantage of the gravel emergence test as conceived (namely, the circumventing of precise weights of gravel and additions of water) failed to provide adequate control of the water available to the seed. We now believe that sand (1- to 0.1-mm size) at 4% moisture, with the seed planted at 1½-in. depth, evaluates the emergence potential more accurately.

When hypersensitive seedlot D had access to a continuous supply of water, as on a "very wet" blotter (Table 3, test no. 6), it germinated less completely than when highly hydrated seeds were placed in plastic envelopes without access to additional water (Fig. 2). In the plastic envelopes, once a few seeds germinated and the seedlings grew, water from the wet seeds was redistributed into fresh weight and additional seeds could then germinate. In other tests we have observed that seeds that fail to germinate at continuously high moisture often will germinate when they are put in a somewhat drier environment.

Hunter and Dexter (1) reported that moisture contents of 31% were required for germination of segmented multigerm seeds. The degree of processing to remove the corky material will influence the requirement.

From this investigation we are now able to quantify some aspects of the water requirements for germination of sugarbeet. From Fig. 2 we note that seedlot A germinates well at 30% moisture and D at 40%. Fruits of seedlots A and D weigh very close to 0.01 g (10 mg) each.

[7]Oral communication from T. F. Cuddy, Biologist, Seed Germination and Physiology, Scientific Services Laboratory, Ottawa, Ontario, Canada.

Therefore, a fruit of seedlot A requires 3.0 mg of water for its seed to germinate, and a fruit of D requires 4.0 mg. The fine sand at 4% moisture would have 1 g of water on the surface of 25 g of sand (air-dry basis). We determined that 200 g of air-dry sand occupied 118 ml of volume. If we assume no compaction of the moistened sand, then at 4% moisture, 14.75 ml of sand would have 1 g of water on its surface. If the water on the surface of the sand were all available, less than 0.06 ml of sand could supply the water required for germination of one seed of either of these seedlots.

The addition of 3.47 mg of water to each fruit in seedlot A and 3.20 mg to each in D, by immersion in water and then planting in sand at 4% moisture, depressed emergence of seedlot A by 16% and of D by 28%, as compared with planting dry fruits (Table 4, test no. 3). Hydrating the seeds before planting apparently created an excess of water surrounding the seed that was enough to depress germination.

Since seedlots A and D were a single cultivar, the differential response to water absorption must be related either to differing environment during development and maturation of the fruit and seed or possibly to maturity at harvest. No specific data are available to determine which conditions could be responsible. Some fruits of seedlot D were slightly less processed than A, and this could have contributed to the greater water uptake by D. Immature fruits process more difficultly and less completely, and they absorb more water than ripe fruits.[8] Thus, differential maturity may have contributed to the more variable and greater water absorption by seedlot D.

Summary

Two commercially grown seedlots of a single sugarbeet cultivar, one very sensitive to the quantity of water available during germination and the other relatively insensitive, were tested to demonstrate a marked differential in germination and emergence, which was correlated with the quantity of water available to the seed.

The relatively insensitive seedlot absorbed water more slowly, and after 48 hours of immersion in water, it had absorbed less water than the very sensitive one. Whenever a system contained an excess of free water, germination of the very sensitive seedlot was depressed, often significantly. Whenever water was relatively limited and slowly available, germination of the very sensitive seedlot approximated that of the less sensitive one.

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[8]Unpublished data of F. W. Snyder.

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