Some Seed-Soil Moisture Studies with Sugar Beets[1]

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In agricultural practice, soil moisture is rarely optimal for sugar beet (Beta vulgaris) seed germination and emergence. Experience as well as controlled experiment (2)[3] has shown that in sugar beets germination is slow at low soil moisture contents, when other seeds may be germinating well. A number of investigations (1, 3, 4) have proposed various reasons for this and have indicated that probably one of the most critical conditions is that of the moisture relationship between seed and environment. It was, therefore, the purpose of this study to examine some of the specific moisture requirements of sugar beets for germination, to determine experimentally what the optimum and the critical conditions for germination might be and to establish some sort of time schedule for the various phases of water uptake and germination.

Experimental Procedure and Results

Segmented seed (US 215x216) screened through 8/64" mesh on 1/12" mesh screens were used in all experiments. The soil was a Brookston clay loam taken from the plow layer of the College farm at East Lansing, Michigan. All experiments were carried out at approximately 70°-75° F.

Experiment I. In a series of mason jars, air was maintained at a variety of relative humidities (25, 50, 60, 65, 70, 75, 80, 90, 100%) by placing in them various concentrations of H_2SC% as indicated by Wilson (5). Suspended from the inside of the jar cap and above the liquid in the jar was a small perforated metal cup. Within this cup was placed a known number of air dry seed of a known moisture content. At varying intervals these seeds were removed from each of the air tight jars, weighed and returned. When the weight became constant, indicating moisture equilibrium between the seeds and the surrounding atmosphere, the seeds were placed in an air-oven at 102° C. for 24 hours and reweighed so that their moisture contents could be calculated. Table I shows the results of this experiment.

TABLE I. Moisture content of sugar beet seeds exposed for various periods of time to air at the relative humidities shown (75° F.).

Time in Hours	Percentage moisture content of seeds. Relative Humidity of Atmosphere in Jars								
	25%	50%	60%	65%	70%	75%	80%	90%	100%
0	5.74	5.74	5.74	5.74	5.74	5.74	5.74	5.74	5.74
24	6.03	8.12	7.75	9.83	12.10	11.65	11.99	18.33	25.18
48	6.13	9.23	8.57	10.60	12.56	13.65	13.35	19.48	27.95*
168	6.73	9.63	9.02	11.03	13.21	13.96	14.07	18.65*	28.82*

*Indicates that the seeds became very moldy.

[1] Approved for publication by the director of the Michigan Agricultural Experiment Station as Journal Article No. 1,139.

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[3] Numbers in parentheses refer to literature cited.

In no case was there any germination of the seeds. From the table it can be seen that at every relative humidity the seeds approached equilibrium in about 48 hours. Seed lying in soil too dry for germination should therefore approximate its maximum moisture content in about 48 hours, and should never exceed about 29% moisture content.

Experiment II. A 200-gram sample of the Brookston soil (through 10/64" screen) was placed in each of a series of mason jars and brought up to the following range of moisture contents (8, 10, 12, 14, 16, and 18%) by adding appropriate amounts of water and mixing with a spoon. There were seven jars for each moisture content. The jars were then closed and the soil was allowed to come to equilibrium over a period of three or four days. During this time the jars were shaken two or three times a day. Air dry seed of known moisture content was then added to the soil in each of the jars. The soil was not packed around the seeds. At intervals shown in Table II, a jar at each moisture content was opened and the moisture content of the seeds therein was determined.

The specific purpose of this experiment was to determine how readily the seeds could obtain moisture from soils of different moisture content. Table II shows the results.

TABLE II. Percent moisture reached by sugar beet seeds after various intervals in contact with Brookston soil at the moisture contents shown. (75° F.)

Time in Hours	Percent moisture in seed in soil at various moisture contents — Moisture content of the soil					
	8%	10%	12%	14%	16%	18%
0	7.03	7.03	7.03	7.03	7.03	7.03
½	15.00	17.80	19.75	21.00	17.80	20.19
1	19.62	22.35	15.05	23.75	21.80	22.37
1½	19.42	23.64	23.94	25.53	24.32	24.97
2	20.02	24.57	24.98	24.17	22.40	27.48
4	21.80	26.24	29.80	31.38	31.84	28.78
24	22.07	24.95	29.87	32.53	33.04*	34.99*
48	20.70	25.83	29.90	32.94*	33.64*	35.78*

* Seeds beginning to sprout.

This experiment was not carried out past 48 hours as the results of Experiment I indicated that within that period of time the seed should have come to equilibrium with its environment. Results here indicate that when in contact with soil, irrespective of its moisture content, the seeds had practically attained equilibrium after a period of four hours and that by 48 hours those seeds in the soils of higher moisture content had already begun to sprout. Apparently, films of free water (14-18%) on the soil particles can supply moisture to the seeds more rapidly (4 hrs. vs. 48 hrs.) than can saturated air (100% R. H.), and, in addition, can bring the seeds to moisture contents sufficiently high for germination. In soils with a moisture content of 12% and lower, the seeds appear to have exhausted the soil's moisture supply at the end of 4 hours and do not subsequently become more moist. This suggests a break in the capillary supply system particularly at 12% and that in the soils at 8 and 10% the relative humidity of the soil air is between 90 and 100% relative humidity (compare with Table I).

Experiment III. Seed of known moisture content was immersed into a beaker of H_2O at 75° F. Samples were removed at appropriate time intervals for moisture content determination until equilibrium was attained. The purpose of this experiment was to ascertain the rate at which sugar beet seeds could take up water when completely surrounded by water. Table III shows the results of this experiment.

TABLE III. Percent of moisture in sugar beet seeds after various periods of immersion in water.

	Length of time in direct contact with water, in hours							
	0	½	1	1½	2	4	24	48
Moisture Content	7.03	41.38	40.44	43.13	42.57	48.92	50.20	51.65

The results indicate that within the first four hours the seed became almost completely saturated with water. During the first half hour of soaking, the seeds absorbed water very rapidly and to a percentage definitely higher than that required for germination (see Exp. II). Periods of time required to reach a moisture content of approximately 30% would then be about 48 hours in air at 100% relative humidity, 4 hours in loose contact with damp or moist Brookston soil and ½ hour in water.

Experiment IV. A series of mason jars was made up with Brookston soil of varying moisture content as in Experiment II. In this case the range was 10, 12, 14, 16, 18, 20 and 22% moisture. For each different moisture content ten jars were prepared. Ten lots of seed were made up, with moisture contents of 5, 7, 10, 14, 18, 20, 22, 26, 30 and 35%. In each of the jars ten seeds were planted at ½ inch depth by pouring a measured amount of loose soil on top of the seeds. The soil was not packed around the seed. The moisture content of the seed planted in each jar of a series was different so that for each different soil moisture there was a complete range of seed moistures. Rates of germination were observed.

Due to lack of space the results of only two seed moistures (5 and 14%) will be presented. These two particular moisture contents were chosen as 5% approximates the moisture content of air dry seed and 14% approximates that of seed stored at a relative humidity of 75-80% (see Table I), which is the maximum for safe storage. Figures indicate the number of sugar beet seeds germinated *in* the different soils at varying times after planting. In soils at 22% moisture, seeds were drowned and no sprouts appeared.

Experiment V. Flats of Brookston soil were prepared so that each contained at the beginning of the experiment the same amount of soil of the same moisture content (11.8%). Seeds of known moisture content (5.24%) were planted therein at half inch depth in separate rows. There were ten seeds to each row and the rows were 22 inches long. There were 5 rows for each treatment, which consisted of the following: Following the planting, water was applied from a pipette to the surface of the soil over each of the rows of seeds in the following amounts: 0, 5, 10, 15, and 20 cc. per row. 10 cc. per row would amount to approximately 25 gal. per acre. Rates of emergence following these treatments were noted. In order to insure a more constant moisture content of the soil in the flats during the experiment, they were placed in the basement of the greenhouse, which has a relative humidity of about 80%. Table V indicates the results obtained.

In this soil, at a critical moisture content, a small amount of water in contact with the seed gave marked acceleration in emergence. Since the seeds were about 2" apart, most of this water was probably wasted. It seems likely that one drop of water directly on each seed would have been highly effective in producing rapid emergence, and that the amount per acre could have been reduced to a matter of a tew quarts.

TABLE IV. Number of sprouts emerged after the periods shown, when seeds of 2 moisture contents were planted in soils of various moisture «

Time after Planting	Soil Moistures 10%		12%		14%		16%		18%		20%	
	Seed Moistures 5%	14%	5%	14%	5%	14%	5%	14%	5%	14%	5%	14%
24 hrs.	0	0	0	0	0	0	0					
48 hrs.	0	0	0	0	1	2	1					
72 hrs.												
96 hrs.												
120 hrs.												
144 hrs.												

Discussion

From the results of these experiments it may be seen that in a Brookston soil air dry seeds germinated only between 12% and 20% soil moisture. Seeds did not germinate in air in relative humidities of even 100%. At this relative humidity the seeds themselves attained a value of almost 29% moisture. This leads one to conclude that unless the seed can absorb enough moisture to raise its- moisture content above 29% it will not germinate.

Now, the relative humidity of the vapor pressure of the water in soils of 12, 14, 16 or 18% moisture content is 100%,. It may therefore be reasoned that the seed which sprouted in soils of those moisture contents was able to draw water from some other source than the soil atmosphere. In other words, germination depended upon the seed coming in contact with some surface of free water. However, too great an amount of free water about the seed for a period of several days inhibited germination as it limits the amount of air that the seed may absorb.

TABLE V. Number of seeds germinated (out of 50 planted) at various intervals after planting under various treatments.

Time after Planting	Soil treatment—amount of water per row: No water	5 cc.	10 cc.	15 cc.	20 cc.
24 hrs.	0	0	0	0	0
48 hrs.	0	0	1	5	7
72 hrs.	1	1	2	16	20
96 hrs.	3	3	5	21	36
120 hrs.	5	8	14	35	40
144 hrs.	5	15	27	45	48
168 hrs.	7	21	32	47	48

Once in contact with free water surface, seeds were able to absorb water rapidly. Their moisture content was increased, on soaking in water, from an air dry condition (about 5% moisture) to one favorable for germination (about 35% moisture) in half an hour. In damp soil this required about 4 hours. Thus seeds absorbed quickly free or capillary moisture with which they were in contact. It would appear that only that water which was in the seed or which was in free films within a relatively small radius was instrumental in actually effecting germination.

Summary

1. Seeds failed to germinate in air at 100% relative humidity. At this high humidity a maximum of 29% moisture was absorbed.

2. In the Brookston clay loam germination did not occur unless the seed took up somewhat over 30% of moisture. Germination took 24 hours or more, but water absorption was complete in about 4 hours.

3. Seeds immersed in water took up over 30% of water in one-half hour.

4. Free water films appeared to be necessary for germination.

5. In soils near the lower critical moisture content for germination, planting seeds of higher moisture content speeded up emergence and adding small amount of water in contact with the seed, induced germination even in soils drier than the critical point.

Literature Cited

1. DEXTER, S. T. Preliminary Findings on the Use of Plant Hormones as seed treatments for Sugar Beets. Mich. Agr. Exp. Sta. Quarterly Bui. 24: 245-248. 1942.

2. DONEEN, L. D., and J. H. MACGILLIVRAY. Germination (Emergence) of Vegetable Seed as Effected by Different Soil Moisture Conditions. Plant Physiology 18: 524-529. 1943.

3. STOUT, M., and B. TOLMAN. Factors Affecting the Germination of Sugar Beet and Other Seeds, with Special Reference to the Toxic Effects of Ammonia. J. Ag. Rs. 63; 687-713. 1941.

4. TOLMAN B., and M. STOUT. Toxic Effect on Germinating Sugar Beet Seed of Water-Soluble Substances in the Seed Ball. J. Ag. Res. 61: 817-830, 1940.

5. WILSON, R. E. Humidity Control by Means of H_2S0_4 with Critical Compilation of Vapor Pressure Data. Jour. Ind. and Eng. Chem. 13: 326-330. 1921.