The Effects of Limited Moisture on Germination and Initial Growth of Six Grass Species[1]

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Vast areas of range land in the southwestern states which were formerly dominated by perennial grasses are now badly in need of revegetation. This condition presents a problem in the selection of grass species for reseeding. Growing-season precipitation results from convectional storms and is erratic in distribution both as to time and location. This, coupled with the high evaporation rate from sparsely vegetated loamy sand and sandy loam soils characteristic of much of the region, makes for low effectiveness of precipitation. Therefore, species selected for reseeding should be those which are best adapted to germination and survival under conditions of limited moisture.

The objectives of this study were to determine the effect of different degrees of moisture stress on time required for germination, total germination, and initial seedling growth of six warm season grass species.

Literature Review

Ayres (1952) stated, "to obtain moisture from the soil and germinate, a seed must overcome two main forces: (1) the surface force action of the soil particles which accounts for the moisture retention properties of the soil, usually referred to as moisture tension; and (2) the osmotic force action which is due to the dissolved materials in the soil solution." He also showed that when moisture in fine sandy loam soil was decreased from 12.4 to 7.2 percent, emergence time for onion seed was increased more than 48 hours and total emergence was decreased approximately 40 percent. With percentage of moisture decreased to 6.1, time of emergence was decreased approximately 80 percent as compared to seed germinated in soil containing 12.4 percent moisture.

Doneen and MacGillivray (1943) in tests with seeds of 15 vegetable crops found that emergence varied from 5 to 14.5 days (approximate figures as interpolated from a graph) under moisture conditions controlled from 8 to 18 percent in Yolo fine sandy loam.

Uhvits (1946) tested the germination of alfalfa seeds on substrate supplied with solutions of sodium chloride and mannitol at osmotic concentrations ranging from 1 to 15 atmospheres (atm.) and found that the higher the concentration of mannitol and sodium chloride, the lower the rate and percentage of germination of alfalfa seeds. The sodium chloride was more inhibitory than was the mannitol at concentrations of equal osmotic concentrations. Therefore, she concluded that differences in response to the two solutions at isotonic concentrations suggested a toxic effect of the sodium chloride. She also found that recovery of seedlings was greater when the seeds were treated with mannitol.

Powell and Pfeifer (1956), using mannitol mixtures as germination medium for Cheyenne winter wheat, found marked decreases in the vigor of different selections at 11.0 atm. osmotic concentration as compared to

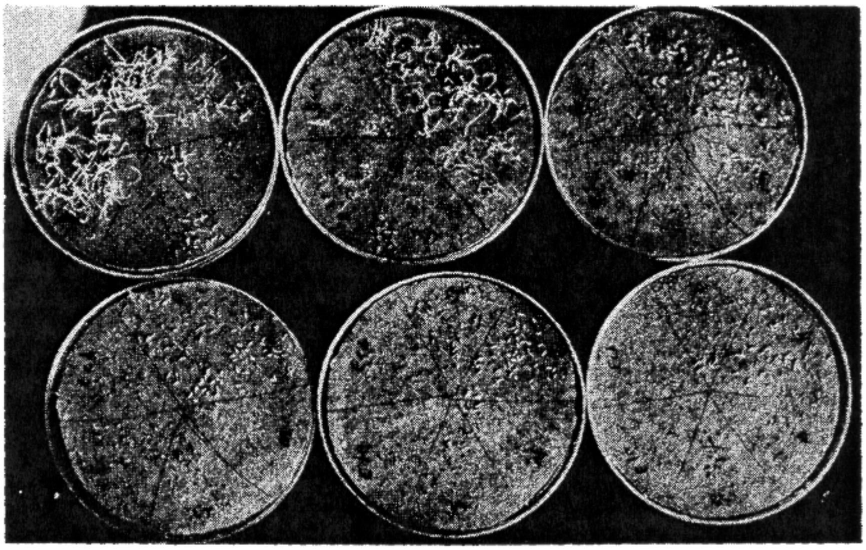

FIGURE 1. Germination of caryopses and growth of seedlings of six grass species, at six levels of moisture stress, after 60 hours at room temperature. Upper row left to right, 0.3, 3.0, and 7.0 and lower row left to right, 11.0, 15.0, and 20.0 atm. osmotic concentration. B = black grama, H = tobosa, M = bush muhly, S = mesa dropseed, Ele = lehmann lovegrass, and Ech = boer lovegrass.

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to those germinated at 7.0 atm.

McGinnies (1960), using six cool-season range grasses, found that under high moisture stress all species germinated better at 20 degrees than at 10 or 30 degrees C.

Procedure

The species tested in this study were black grama[2] (*Bouteloua eriopoda* (Torr.) Torr.), bush muhly (*Muhlenbergia porteri* Scribn.), mesa dropseed (*Sporobolus flexuosus* (Thurb.) Rydb.), tobosa (*Hilaria mutica* (Buckl.) Benth.), lehmann lovegrass (*Eragrostis lehmanniana* Nees), and boer lovegrass (*Eragrostis chloromelas* Steud.). The germination tests were made in twenty-four, 5½-inch petri dishes with the substrate, two thicknesses of standard germination blotter paper, marked in six equal sections resembling the pieces of a pie. The six sections of each substrate were marked with a symbol corresponding to each of the above mentioned species and fifty caryopses of the appropriate species were placed in each section. Only undamaged, mature appearing, caryopses were used in the experiment. The 24 dishes were arranged in six groups of four and treated with a water-mannitol solution of 0.3, 3.0, 7.0, 11.0, 15.0 or 20.0 atm. osmotic concentration. The substrate of each dish, in each group of four, was moistened with 10 ml. of one of the water-mannitol solutions. The various degrees of moisture (atm. osmotic concentration) were developed through the use of water-mannitol solutions as described by Helmerick and Pfeifer (1954), i.e.,

$$g = \frac{PVm}{RT}$$

where g = grams mannitol required, P = desired osmotic concentration, V = volume in liters, m = molecular weight of mannitol, R = .08205 liter atm. per degree per mole, and T = absolute temperature.

Recent unpublished investigations by one of the authors indicated that lehmann lovegrass germinates poorly unless scarified. Therefore, preliminary tests were conducted employing various techniques of scarification of the caryopses of this species. Scarification, rubbing the caryopses between two pieces of very fine sandpaper, gave 95 to 100 percent germination compared to percentages of 4 to 13 for unscarified ones. Following these findings the caryopses of lehmann lovegrass were scarified with sandpaper prior to the initiation of the experiment.

All species were germinated at room temperature (25° C.), and germination counts were made at 36-, 60-, 84-, 108-, 132-, and 156-hour intervals. A caryopsis was considered as germinated when a plumule or radicle had broken through its pericarp. After the 156-hour interval observation, one replication of each treatment was selected at random, and the lengths of the plumules and radicles were recorded by species and osmotic concentrations.

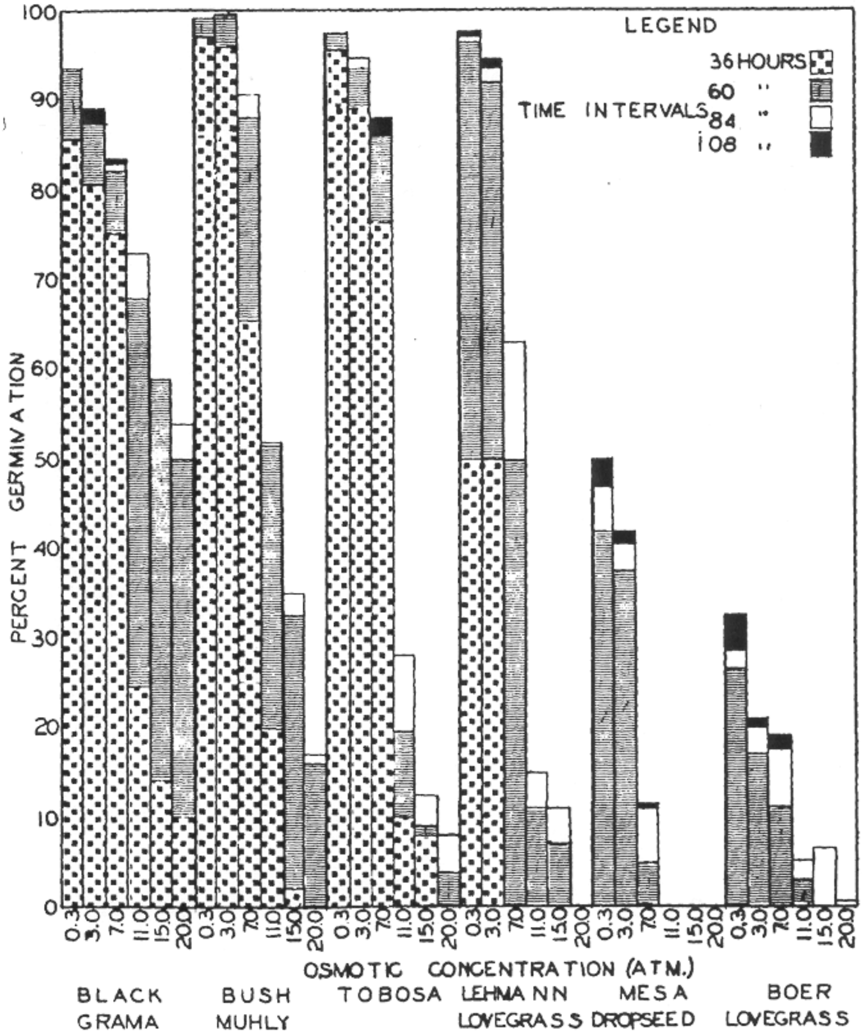

FIGURE 2. Germination by time interval of six grass species at six levels of moisture stress (atm. osmotic concentration).

[2] *Plant names agree with "Standardized Plant Names." 1942. Kelsey, Harlan P. and William A. Dayton. 2ed. J. Horace McFarland and Co., Harrisburg, Pa.*

Results and Discussion

After a time lapse of 60 hours, one replication of each treatment was selected at random and photographed (Figure 1). The photograph is representative of the entire experiment as it appeared at this time.

A graphic summary of the germination percentage of all species, at all levels of osmotic concentration employed, after 36, 60, 84, and 108 hours is presented in Figure 2. No caryopses germinated after 108 hours.

Delay in germination due to osmotic concentration. An osmotic concentration of 3.0 atm. did not greatly delay germination of the species tested. Germination of lehmann lovegrass was greatly delayed by 7.0 atm. osmotic concentration; none of the others was. The caryopses of mesa dropseed and boer lovegrass did not begin to germinate until after the 36-hour observation. All the species which germinated in appreciable numbers at osmotic concentrations of 11.0 and higher were delayed by these higher levels of moisture stress (Figure 2).

Reduction in total germination due to osmotic concentration. An analysis of variance was calculated on the numbers germinated in each replication, after 60 and 108 hours, of all species at 0.3, 3.0, and 7.0 atm. osmotic concentration, and a separate analysis was made of the black grama, bush muhly, and tobosa results at all levels of osmotic concentration. The germination results of lehmann lovegrass, boer lovegrass, and mesa dropseed at 11.0, 15.0, and 20.0 atm. osmotic concentration were excluded from the statistical analyses because these species germinated poorly at these levels of moisture stress (Table 1). The mean numbers germinated and their appropriate l.s.d. values, and the mean numbers germinated by lehmann lovegrass, boer lovegrass, and mesa dropseed at 11.0, 15.0, and 20.0 atm. osmotic concentration are presented in Table 1. It should be re-emphasized that these trials were conducted at 25° C., which may not be the optimum temperature for all the species tested.

Table 1. Average number of caryopses germinated (of 50) by six grass species at six levels of moisture stress (atm. osmotic concentration).

		Species						
Osmotic concentration	Time lapse	Black grama	Bush muhly	Tobosa	Lehmann lovegrass	Mesa dropseed	Boer lovegrass	L.S.D.
(atm.)	(Hours)							
0.3	60	46.75	49.50	48.75	48.25	21.00	13.00	8.12
	108	46.75	49.50	49.00	48.75	25.00	16.25	5.96
3.0	60	43.75	49.75	46.75	46.00	18.75	8.50	8.12
	108	44.50	49.75	47.25	46.75	21.00	10.50	5.96
7.0	60	41.25	44.00	43.00	25.00	2.50	5.50	8.12
	108	41.75	45.00	44.00	31.50	5.75	6.75	5.96
11.0	60	33.25	25.50	9.75	*7.75*	*0.00*	*1.75*	4.55
	108	35.75	25.75	14.00	*9.75*	*0.00*	*2.25*	4.79
15.0	60	28.25	16.50	4.50	*3.50*	*0.00*	*0.00*	4.55
	108	28.25	17.75	6.25	*5.50*	*0.00*	*3.25*	4.79
20.0	60	23.75	8.00	2.00	*0.00*	*0.00*	*0.00*	4.55
	108	27.00	8.50	3.00	*0.00*	*0.00*	*0.25*	4.79
L.S.D	60 hours	4.70	4.70	4.70	3.28	3.28	3.28	
L.S.D.	108 hours	5.57	5.57	5.57	4.56	4.56	4.56	

Note: L.S.D. values do not apply to the figures in italics.

Germination of mesa dropseed would probably have been higher, especially at the lower levels of moisture stress, if the caryopses of this species had been scarified. However this low germination did not detract from the overall aspect exhibited by this species, i.e., decrease in germination with increase in osmotic concentration (Figure 2). The failure of mesa dropped to germinate at 11.0 atm. osmotic concentration can not be completely attributed to the absence of scarification, because reduction in germination of this species due to increasing osmotic concentration from 0.3 to 3.0 and 3.0 to 7.0 atm. was greater than that of any other species tested (Figure 2 and Table 1).

Germination of boer lovegrass, at the lower levels of moisture stress, would probably have been higher if the caryopses of this species had been scarified. Percentage of reduction in germination of this species, due to increasing osmotic concentration from 0.3 to 7.0 atm., was only slightly greater than that of the species least reduced under these conditions, i.e., black grama, bush muhly, and tobosa (Table 1).

The caryopses of lehmann lovegrass were scarified and the reduction in percentage of germination as a result of increasing osmotic concentration from 0.3 to 7.0 atm., was second only to that of mesa dropseed. Consequently it is not likely that lack of scarification, in the case of mesa dropseed and boer lovegrass, reduced the reliability of the results.

Final germination of black

Table 2. Mean radicle and plumule growth (in mm.) of six grass species, after 156 hours at room temperature, when germinated and grown in petri dishes at six levels of osmotic concentration

Osmotic Concentration (atm.)	0.3	3.0	7.0	11.0	15.0	20.0
MEAN RADICLE GROWTH						
Lehmann lovegrass	4.08 a*1*	4.21 b 1	1.48 b 1	<1.00	<1.00	#
Mesa dropseed	6.77 a 1	3.24 b 1	.38 b 1	#	#	#
Boer lovegrass	9.38 a 1	10.50 a 1	.43 b	<1.00	<1.00	<1.00
Bush muhly	10.89 a 1	13.07 a 1	10.16 a 1	4.36	<1.00	<1.00
Black grama	17.21	13.49 a .	8.33 a	2.19	<1.00	<1.00
Tobosa	25.71	19.55	1.95 b	<1.00	<1.00	<1.00
MEAN PLUMULE GROWTH						
Mesa dropseed	10.04 b 1	7.60 a 1,2	1.00 b 2	#	#	#
Lehmann lovegrass	11.38 ab 1	9.21 a 1	3.53 a	<1.00	1.00	#
Boer lovegrass	14.88 a 1	9.20 a 1	1.71 b	<1.00	<1.00	<1.00
Tobosa	19.47 c	8.28 a	1.62 b	<1.00	<1.00	<1.00
Black grama	20.57 c	13.14	5.19 a	2.12	<1.00	<1.00
Bush muhly	31.81	25.48	12.48	4.71	<1.00	<1.00

*Any two column means not followed by the same letter are significantly different, and any two row means not followed by the same number are significantly different.

#None germinated.

grama was significantly greater than all other species at 11.0, 15.0, and 20.0 atm. osmotic concentration, (l.s.d. values Table 1), and final germination of bush muhly was significantly greater than all other species except black grama at these levels. There was no significant difference in total germination of black grama, bush muhly, and tobosa at 0.3, 3.0, and 7.0 atm. osmotic concentration, while total germination of these species was significantly greater than that of mesa dropseed and boer lovegrass at these levels, and greater than lehmann lovegrass at 7.0 atm. Total germination of lehmann lovegrass was significantly greater than that of mesa dropseed and boer lovegrass at 0.3, 3.0, and 7.0 atm. osmotic concentration, and total germination of mesa dropseed was greater than that of boer lovegrass at these levels.

Whether the seedlings which developed at osmotic concentrations of 11.0, 15.0, and 20.0 atm. would have survived if supplied with adequate moisture was not determined. It is the authors' opinion that they would. However, assuming a light shower on caryopses capable of germination under conditions of very limited moisture, followed by several days during which no additional precipitation occurred, a goodly portion of a seed crop might perish due to insufficient moisture for seedling establishment. This may, in part, explain the failure of black grama ranges to reseed themselves after drouth and/or grazing damage. Assuming two or three widely spaced light showers, providing sufficient moisture for germination but insufficient for seedling establishment, an entire seed crop might perish. The fact that black grama is a very poor seed producer would also lessen the possibility of propagation of this species, should an appreciable percentage of seed perish as discussed above.

Seedling growth as affected by osmotic concentration. Average lengths of radicles and plumules after 156 hours, of one randomly selected replication of each treatment, are presented in Table 2. Since all replications within treatments appeared to be equal, with respect to growth, and were practically identical in numbers germinated, these measurements are quite representative. Figure 3 is a photographic comparison of the growth of five seedlings of each species, at each level of osmotic concentration, after 180 hours. Analysis of variance, using the R x C table method described by Snedecor (1956), was calculated for both radicle and plumule measurements of all species, of one randomly selected replication of each treatment, at 0.3, 3.0, and 7.0 atm. osmotic concentration. L. S. D. values, for radicle and plumule growth differences within and between species, were calculated for all species at 0.3, 3.0, and 7.0 atm. osmotic concentration (Table 2). The 11.0, 15.0, and 20.0 atm. osmotic concentration observations were not included in the statistical analyses because of a lack of measurable growth at these levels of moisture stress, but these results are shown in Table 2. There was highly significant interaction between species and osmotic concentration for both radicle and plumule growth.

The vigorous growth of tobosa seedlings at 0.3 and 3.0 atm. osmotic concentration indicates that the species is capable of germination and vigorous growth when moisture is abundant as would be the case immediately after heavy rains in the fine textured soils of tobosa sites. This may be attributable to the relatively high amounts of food stored in the comparatively large starchy caryopses characteristic of the species. Although the caryopses of tobosa germinated well when subjected to high moisture stress, the species is apparently not well adapted to initial growth under these conditions (Table 2).

Bush muhly and black grama are evidently better adapted to make initial growth after ger-

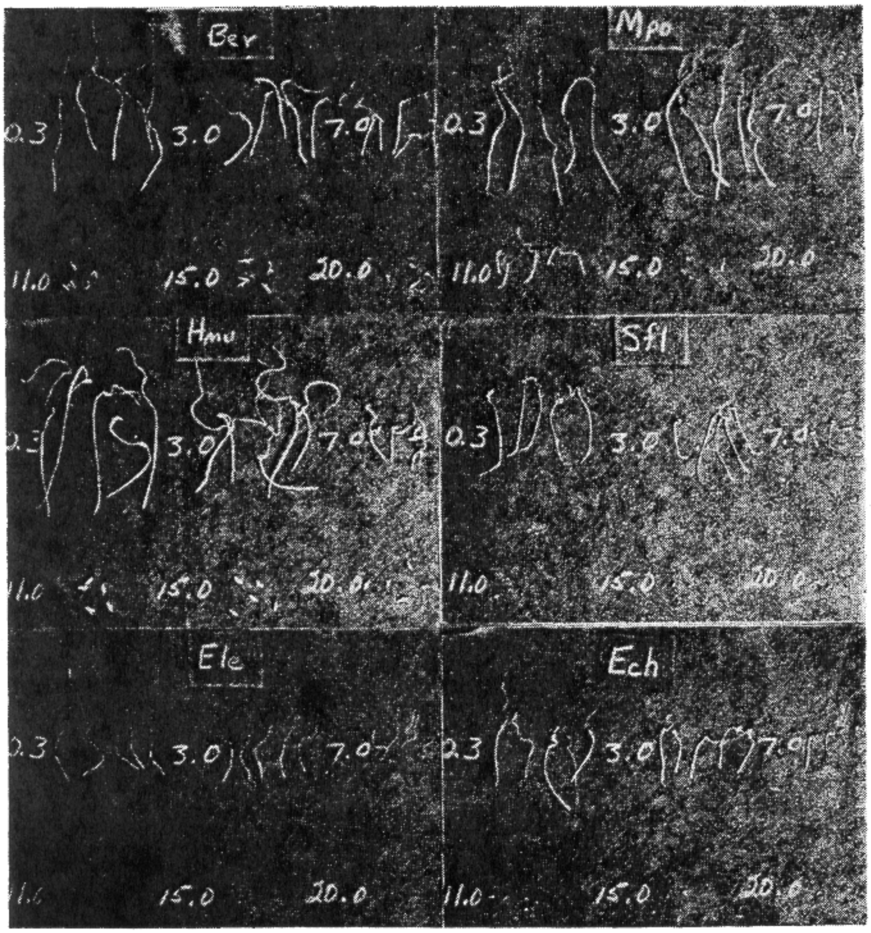

FIGURE 3. Seedling growth of six grass species at six levels of moisture stress after 180 hours at room temperature. The numbers to the left of each group of five seedlings are atm. osomotic concentration. Ber = black grama, Mpo = bush muhly, Hmu = tobosa, Sfl = mesa dropseed, Ele = lehmann lovegrass, and Ech = boer lovegrass.

mination, in situations where moisture is limited, than any of the other species tested. These were the only species whose seedlings developed, to any appreciable extent, at 11.0 atm. osmotic concentration (Table 2). Generally, both of these species made significantly greater growth than the other species tested which are adapted to sandy, well drained sites, at higher levels of moisture stress. However, the management problems associated with black grama and bush muhly should be kept in mind when considering these species for a seeding program, since they will not stand prolonged heavy use. This is particularly true of bush muhly because the plant is very palatable and its growth habit is such that it does not withstand grazing as well as black grama. Probably the only situation in which these species would be practical for reseeding would be in pure stands or in mixtures of only these two species. Such a seeding would be ideal for winter and early spring use, since the culms of both of these species remain partially green during the winter months.

Summary

Two hundred caryopses each of black grama, bush muhly, tobosa, mesa dropseed, lehmann lovegrass, and boer lovegrass were germinated in petri dishes on blotter paper moistened with water-mannitol solutions of 0.3, 3.0, 7.0, 11.0, 15.0, and 20.0 atm. osmotic concentration (degrees of moisture stress). The object of the study was to determine differences, within and among species, in time required to germinate, total germination, and initial growth of seedlings under various conditions of moisture stress.

With the exception of lehmann lovegrass, time required to germinate was not greatly increased by increasing osmotic concentration from 0.3 to 7.0 atm. However, total germination of lehmann lovegrass, boer lovegrass, and mesa dropseed was significantly reduced by increasing osmotic concentration from 0.3 to 7.0 atm., and reduction in total germination of all species was very nearly significant under these conditions.

Generally, the growth of seedlings was significantly decreased by increasing osmotic concentration from 0.3 to 7.0 atm.

Of the species tested, black grama and bush muhly seem best adapted to survival under conditions of limited moisture. Seedlings of these species were the only ones which attained measurable growth when germinated and grown at 11.0 atm. osmotic concentration. None of the species developed measurable seedlings at 15.0 and 20.0 atm. osmotic concentration, but the caryopses of black grama and bush muhly germinated surprisingly well at these levels of moisture stress.

LITERATURE CITED

AYRES, A. D. 1952. Seed germination as affected by soil moisture and salinity. Agron. Jour. 44: 82-83.

DONEEN, L. D. AND JOHN H. MACGILLIVRAY. 1943. Germination (emergence) of vegetable seed as affected by different soil moisture conditions. Plant Phys. 18:524-529.

HELMERICK, ROBERT H. AND R. P. PFEIFER. 1954. Differential varietal responses of winter wheat germination and early growth to controlled moisture conditions. Agron. Jour. 46:560-562.

McGinnies, William J. 1960. Effects of moisture stress and temperature on germination of six range grasses. Agron. Jour. 52:159-162.

Powell, L. M. and R. P. Pfeifer. 1956. The effect of controlled limited moisture on seedling growth of Cheyenne winter wheat selections. Agron. Jour. 48:555-557.

Snedecor, George W. 1956. Statistical Methods. The Iowa State College Press, Ames, Iowa.

Uhvits, Rachael. 1946. Effects of osmotic pressure on water absorption and germination of alfalfa seed. Amer. Jour. Bot. 33:278-285.