Moisture-Temperature Interrelations in Germination and Early Seedling Development of Mesquite[1]

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Highlight

A greater percentage of mesquite seeds germinated and more vigorous seedlings were produced at a simulated soil temperature of 85 F than at 70 or 100 F. Alternating the temperature between 68 (16 hr) and 86 F (8 hr) did not increase the percentage germination as compared to constant 85 F. As temperature increased moisture stress became more critical in the germination process. After 96 hr exposure to the optimum temperature, percentage germination was not suppressed by tensions up to 8 atm, and seedling vigor was not reduced by tensions up to 4 atm. These data indicate that mesquite seed may germinate and the seedlings become established on drier sites when the soil temperature reaches 85 F.

Mesquite (*Prosopis juliflora* var. *glandulosa* Cockr.) produces a "hard" seed that must be scarified before rapid germination will occur (Fisher et al., 1959). Scarification occurs naturally by passage of the seed through the digestive system of herbivores and birds. This method of dissemination coupled with the long life span of mesquite seed allowed invasion into many once-productive southwestern rangelands. A long life span is typical of many leguminous seeds (Mayer and Poljakoff-Mayber, 1963). Unscarified velvet mesquite [*P. juliflora* var. *velutina* (Woot.) Sarg.] seeds may remain viable in the soil for at least 40 years (Tschirley and Martin, 1960).

Little is known concerning optimum environmental conditions for mesquite germination and seedling establishment. Since mesquite reproduces from seed only, knowledge of the range of conditions which allow germination would aid in understanding its ecological behavior. This study reports a segment of investigations underway to clarify the requirements for mesquite seedling establishment.

Materials and Methods

Difficulties encountered in maintaining desired moisture levels in soil media have given rise to the use of aqueous solutions of mannitol in which the available moisture can be adjusted to desired levels. Sugar solutions were used for this purpose as early as 1932 (Crocker and Barton, 1957). The method has been employed recently in studies of drought resistance in winter wheat (Powell and Pfeifer, 1956), in range grasses (McGinnies, 1960; Knipe and Herbel, 1960), in interpretating the ecological range of certain grasses (Knipe, 1968), and for studying germination mechanisms operative in weeds such as scotch thistle (*Onopordum acanthium* L.) (Scifres and McCarty, 1969). The same range of osmotic pressures can be obtained with solutions of sodium chloride, but phytotoxicity of the dissociated ions may confound plant response to moisture stress (Ayers, 1952).

Mesquite seeds collected near Spur, Texas in 1967 and 1968 were used in these studies. Germination response did not vary between the two seed lots and no differentiation is made as to seed age in the discussion. Since the seed coat may restrict germination in mesquite, only scarified seeds were used and 10 to 25 seeds constituted an experimental unit. Each treatment was replicated three to six times in a completely random design. The desired osmotic pressures in solution were attained from the formula given by Powell and Pfeifer (1956).

In one segment of study, the desired number of seeds were placed in 9-cm diameter disposable petri dishes on two No. 2 (coarse) filter papers. The filter papers were saturated with five ml of the mannitol solutions. Germination in mannitol solutions was compared to that in distilled water or 0 atm osmotic pressure. The petri dishes were placed in a germinator alternating between 8 hr light at 86 F and 16 hr dark at 68 F. Blue grama (*Bouteloua gracilis* (H. B. K.) Lag.) caryopses were germinated under the same conditions such that a direct comparison with mesquite seed activity was possible. Three replications of 300 blue grama caryopses per unit were utilized.

In another segment of study, mesquite seeds were placed in 90 ml glass vials on cheesecloth saturated with mannitol solutions of the desired moisture tension. The mesquite seeds were placed directly on the moistened cheesecloth. A plastic cap fitted with a glass tube in the center was placed on each vial. All openings except the end of the glass tube were sealed with lanolin paste and the vials submerged in water baths at 70, 85, or 100 F. The surrounding water maintained a constant temperature in the vial. The anterior of the glass tube extended above water line to allow gas exchange. One pint plastic cups containing sand were planted to mesquite seeds and placed in the water baths as a check against the germination and growth activity of control treatments in the vials. The sand was kept moist and temperature was monitored throughout the studies with a thermograph. The variation was no more than one degree at any temperature.

Mesquite seeds with the radicle emerged to 2-mm were considered germinated. Response was evaluated by periodically weighing the germinating seeds, counting germination, and measuring rate of radicle and hypocotyl elongation. Most experiments were terminated at the end of seven or ten days due to the size attained by the seedlings under some treatments. A square-root transformation was applied to the number of mesquite seeds germinated before statistical analysis. The data were then converted to percentage germination for presentation. Weights were converted to percentage of the seed weight prior to rehydration. The percentage fresh-weight-increase data were transformed to the arcsin of the square root before regression analyses were conducted. The radicle and hypocotyl lengths were not transformed prior to analysis.

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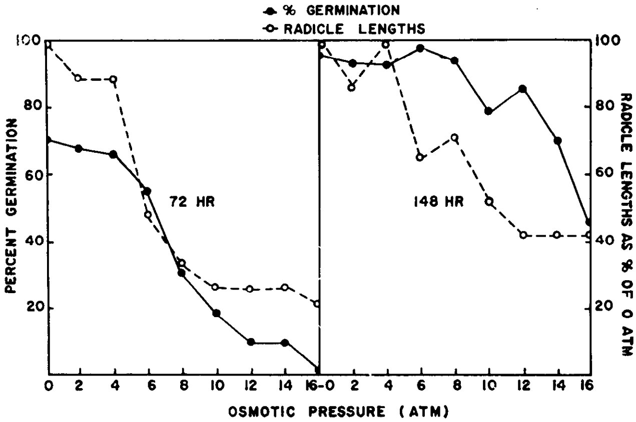

FIG. 1. Percentage germination and radicle elongation of mesquite in a 68 to 86 F alternating temperature after 72 and 142 hours in medias of various osmotic pressures.

Results and Discussion

Seventy percent of the mesquite seeds germinated in distilled water after 72 hr in a 86 to 68 F alternating temperature regime (Fig. 1). Percentage germination was not significantly decreased until at least 6 atm moisture tension was reached. A noticeable decrease in radicle lengths occurred at 2 and 4 atm, but primary root elongation followed the same trend as percentage germination. After 148 hr, 96% of the mesquite seeds under no moisture stress germinated. No significant decrease in germination occurred until 10 to 12 atm moisture tension was reached. Radicle elongation after 148 hr followed the same general trend as shown for 72 hr, but the magnitude of difference was decreased. A moisture tension of 6 atm was required before radicle elongation was reduced significantly after 148 hr. Germination of blue grama was depressed by 6 atm (data not shown), which correlated well with Knipe's (1968) report. Thus, it would be expected that mesquite and blue grama could become established on sites similar in available moisture.

"Optimum" germination conditions result in prompt and complete seedling stands (Crocker and Barton, 1957). Mesquite seeds maintained at 85 F in sand culture emerged within 24 hr after planting (Table 1). Those at 100 F required 42 hr, and those at 70 F required 72 hr for emergence. Total emergence at 72 hr was greater at 85 than at 100 or 70 F. Hypocotyl lengths reflected differences in seedling vigor and emergence rate.

Table 1. Time (hr) required for first emergence, and emergence (%) and hypocotyl lengths (mm) at 72 hr after planting mesquite seeds in moist sand at 100, 85, or 70 F.[1]

Sand temp	Time to first emergence	Emergence at 72 hr	Hypocotyl lengths at 72 hr
100	42	42	9
85	24	90	12
70	72	30	3[2]

[1] Represents average of three experiments.
[2] Still in "crook" stage at 72 hr.

Table 2. Percentage germination and radicle lengths of mesquite seedlings at 100, 85, and 70 F as affected by various levels of moisture tension in the germination media after 24, 48, and 96 hours.[1]

Osmotic Pressure (atm)	Activity at time intervals (hr) after wetting: 24[2]				
	24[2]	48		96	
	% germination	% germination	Radicle length (mm)	% germination	Radicle length (mm)
			100 F		
0	26 ab	38 b	5 d	46 b	19 b
2	26 ab	28 bc	4 de	34 bc	17 bc
4	8 c	11 bc	3 de	20 cd	16 bcd
8	1 d	6 cd	2 ef	13 d	15 bcd
16	0 d	0 d	0 f	3 e	2 g
			85 F		
0	47 a	90 a	18 a	90 a	23 a
2	45 a	88 a	17 a	88 a	24 a
4	28 ab	86 a	14 b	86 a	25 a
8	17 bc	81 a	11 c	81 a	19 b
16	0 d	17 bc	3 de	34 bc	13 cde
			70 F		
0	4 c	36 b	4 de	37 b	13 cde
2	0 d	17 bc	3 de	28 bcd	12 def
4	0 d	13 bc	3 de	28 bcd	11 ef
8	0 d	6 cd	2 ef	25 bcd	10 f
16	0 d	0 d	0 f	13 d	4 g

[1] Means within an evaluation time followed by the same letter are not significantly different at the 5% level.

[2] Radicle measurements not taken until 48 hr.

Germination was delayed at 70 F constant temperature (Table 2). Only 4% of the seeds under no moisture stress germinated after 24 hr. This explains the delayed emergence from sand media at the low temperature (Table 1). There was little effect of moisture stress on the fresh weight changes of mesquite seedlings at 70 F until sometime after 48 hr (Table 3) although there was a reduction in germination at 48 hr. Emergence activity from sand media would indicate that moisture stress probably exerted its greatest influence after 72 hr. After 72 hr, few of the seedlings at 70 F and under moisture stress were germinated and seedling vigor was low (Fig. 2).

Germination and early seedling growth of mesquite was consistently favored by a constant temperature of 85 F. There was no great change in percentage fresh-weight increase of seedlings due

Table 3. Regression coefficients for the effect of moisture tension in the germination media on the fresh weight increases of mesquite seedlings after 16, 24, 48, or 96 hr at three temperatures (°F).

Germination temp	b-value at time interval 16	24	48	96
100	–2.11*	–2.20*	–2.77*	–1.01
85	–0.43	–1.14	–3.15*	–3.27*
70	–0.38	–0.72	–0.49	–2.20*

* Significant at the 5% level.

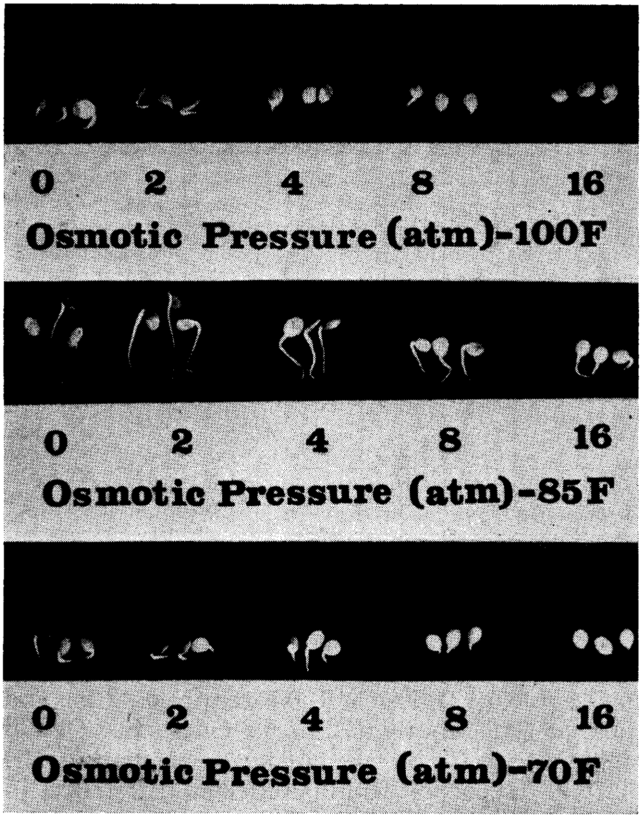

FIG. 2. Appearance of three randomly selected mesquite seedlings from each temperature and moisture level after 72 hours exposure to the germination environments.

to moisture stress at 85 F until after 24 hr. This was obviously due to the significant depression of radicle elongation at 16 atm. At 16 atm moisture tension there is no liquid water available; therefore, mesquite seeds can apparently germinate and initiate early growth from moisture available in the vapor phase. Growth cannot be sustained, however, for over three to seven days at this low moisture availability. Germination was not lowered after 96 hr by 8 atm moisture tension but radicle lengths were suppressed at osmotic pressures of 6 atm or above. The same trend was apparent after 148 hr at an alternating 68 to 86 F temperature. Soil temperatures usually reach 78 to 80 F in the upper four inches of soil around April 5 to 25 on the High Plains of Texas.[2] This would occur about 5 days earlier, on the average, at lower elevations. Thus, spring rains occurring during this period would meet the requisites defined in this study for mesquite germination.

The influence of moisture stress was most apparent on those seeds germinated at 100 F (Table 3). Seeds of many species will germinate at 100 F, but usually, this is considered to be the maximum (Crocker and Barton, 1957). Early imbibition of moisture is primarily a physical process related to properties of the colloids (Mayer and Plojakoff-Mayber, 1963). Thus the rate of water uptake is increased by high temperatures, although the total moisture absorbed may be reduced by high temperatures (Crocker and Barton, 1957). Examination of raw data showed the highest rate of fresh-weight increase to occur at 100 F. The effect of moisture stress could have been masked by the unfavorable temperature after 96 hr. This possibility is reflected by the lack of differences in seedling vigor as expressed by radicle lengths. When no moisture stress was exerted at 100 F, the mesquite seedlings emerged from sand media and survived as long as ample water was available. The seedlings did not survive for more than 10 days under moisture stresses greater than 2 atm at 100 F.

Seedlings recovered if transplanted by three to seven days after germination from the moisture-stress vials to soil in the greenhouse and watered as needed. There was no noticeable difference in the time required for recovery from moisture stress regardless of germination temperature. Seedlings maintained under 8 atm for longer than seven days after germination did not recover.

Conclusions

Mesquite seedling vigor was reduced more than percentage germination by moisture stress. These data indicate that soil temperatures either below (70 F) or above optimum (100 F), or moisture stress within the optimum temperature (85 F), may reduce the probability of mesquite seedling establishment. Further, these data combined with long-term soil temperature data indicate that mesquite seedling emergence probably would not occur in the field in West Texas before the second week in April.

The influence of moisture stress on mesquite germination depended on the ambient temperature. At the high temperature, moisture stress was critical early in the germination process. At the low temperature, growth activity of the mesquite seed was evidently dictated by temperature; and, lack of moisture was not a limiting factor until later in the germination process.

[2] Unpublished data of O. H. Newton, Agricultural Meterologist, USWB, Texas A&M University Agricultural Research and Extension Center at Lubbock, Lubbock, Texas.

LITERATURE CITED

AYERS, A. D. 1952. Seed germination as affected by soil moisture and salinity. Agron. J. 44:82–87.

CROCKER, W., AND L. V. BARTON. 1957. Physiology of Seeds. Chron. Bot. Co., Wattham, Mass. 267 p.

FISHER, C. E., C. H. MEADORS, R. BEHRENS, E. D. ROBISON, P. T. MARIAN, AND H. L. MORTON. 1959. Control of mesquite on grazing lands. Texas Agr. Exp. Sta. Bull. 935. 24 p.

KNIPE, O. D. 1968. Effects of moisture stress on germination of alkali sacaton, galleta, and blue grama. J. Range Manage. 21:3–4.

Knipe, O. D., and C. H. Herbel. 1960. The effect of limited moisture on germination and initial growth of six grass species. J. Range Manage. 13:297–302.

Mayer, A. M., and A. Poljakoff-Mayber. 1963. The Germination of Seeds. MacMillan Co., New York, 236 p.

McGinnies, W. J. 1960. Effects of moisture stress and temperature on germination of six range grasses. Agron. J. 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. J. 48:555–557.

Scifres, C. J., and M. K. McCarty. 1969. Some factors affecting germination and early seedling growth of scotch thistle. Nebr. Agr. Exp. Sta. Res. Bull. 228. 29 p.

Tschirley, Fred H., and S. Clark Martin. 1960. Germination and longevity of velvet mesquite seed in the soil. J. Range Manage. 13:94–97.