The Interrelation of Three Environmental Factors Affecting Germination of Sagebrush Seed[1]

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New and improved range management practices for sagebrush infested rangeland have developed rapidly during the past decade. The use of chemicals to control sagebrush is becoming widely accepted. In order to understand better what range management practices should follow a sagebrush eradication program, the factors affecting sagebrush seed germination and establishment must be known.

A review of the literature shows that little has been published about germination of sagebrush seed. Pechanec *et al.* (1954) state that young sagebrush seedlings are found early in the spring. Van Dersal (1938) and Stoddart and Smith (1943) published germination percentages of 35 and 52 percent, respectively, but neither article described the conditions under which these percentages were obtained.

Shepherd (1937) conducted single experiments on many different factors affecting germination of sagebrush seed. He found that seed treated with dilute hydrochloric acid (0.001 N) gave about 10 percent higher germination than nontreated seed. In light, sagebrush seed gave approximately twice as much germination as in the dark. Temperature was not found to affect the final germination, but slowed down the rate. Shepherd concluded that a supply of viable seed is probably never a limiting factor to the aggression of sagebrush.

Goodwin (1956) also intensively studied the effect of single factors such as scarification, light, temperature, and free water upon the germination of sagebrush seed. Scarification of sagebrush seed with concentrated sulfuric acid was detrimental to germination. Goodwin agreed with Shepherd that light increased germination. The highest germination was obtained when seed was exposed continuously to light. Goodwin reported that sagebrush seed did not germinate at 7° C. (45° F.) but did at 14° C. (57° F.). The optimum temperature for germination was a constant 20° C. (68° F.). Free water was necessary for maximum germination. Goodwin found further that sagebrush seed taken from a shattering seed head and placed in optimum environmental conditions would germinate immediately.

Although Shepherd and Goodwin contributed much to the understanding of sagebrush seed germination, nothing was done to measure the interrelation of various environmental factors. The purpose of the present investigations was to test the role of light, temperature, and available moisture in the germination of sagebrush seed and to determine their interrelation.

Experimental Procedure

A site predominantly covered with big sagebrush *(Artemisia tridentata)* was selected in the Sheep Mountain region of Albany County, Wyoming, for the collection of sagebrush seed. The seed heads were clipped October 28, 1955, from mature plants and threshed. The seeds were screened to remove coarse chaff and recleaned with an Iowa air blast seed separator. The seeds were then stored at 70° F. until used in this experiment.

As defined by Lawrence *et al.* (1947), germination is, "The development of plantlet from the seed." For a seed to be classified as germinated, its root and epicotyl had to have emerged from the seed coat. The seeds were germinated at 38° F. and 70° F. under both full light as supplied by daylight germinators and total darkness. The germination boxes were placed in double thickness No. 10 brown kraft paper bags for the duration of the experiment as a total darkness treatment.

The available moisture was limited by osmotic solutions of 0, 4, and 8 atmospheres tension. The osmotic solutions were made by using d-mannitol and distilled water. The amounts of d-mannitol and water to provide different atmospheric tensions were calculated by the following formulae (Helmrick and Pfeifer, 1954):

Osmotic pressure (P) $= \frac{gRT}{mV}$

grams of d-mannitol (G) $= \frac{PVm}{RT}$

where:

V = volume in liters
R = 0.08205 liter atmospheres per degree per mole
m = molecular weight of d-mannitol
T = absolute temperature.

The solutions were used to

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Table 1. Average germination of sagebrush seeds at two light intensities and two temperatures.

Temperature (°F)	Light intensity		
	Dark	Full light	Average
	Percent	*Percent*	*Percent*
38	3.5*	16.0	9.8
70	13.3	35.2	24.2
Average	8.4	25.6	
Light and temperature LSD		.05	2.6
		.01	3.6
Light x temperature LSD	.05	3.6	
	.01	5.1	

* Each value is an average of six observations, two for each of the three atmospheric tensions.

saturate ½ inch of quartz sand in a germination box, and 100 seeds were placed on a blotter on top of the sand for each treatment replicate. All treatments were duplicated. An air-tight lid was placed on the germination box to hold moisture conditions constant for a three-week period, after which the total germination percentages were recorded. The data obtained were subjected to analysis of variance.

Results and Discussion

Light intensity proved to be a very important factor in the germination of sagebrush seed. When compared with total darkness, full sunlight resulted in significantly higher germination percentages (Table 1). Three times as many seeds germinated in the light as germinated in the dark.

Even though sagebrush seeds germinate to some extent over a wide range of temperatures (Goodwin, 1956), temperature still plays a vital role in the germination process. Also even though it was previously thought that 7° C. (45° F.) was too low for any germination to occur, an average of 9.8 percent of the sagebrush seeds in this experiment germinated at 38° F. At 70° F. the germination percentage was more than double that obtained at 38° F. The average germination percentage was 24.2 for 70° F. and only 9.8 for 38° F. The difference between the two values was highly significant (Table 1).

The interaction of light x temperature was found to be highly significant. Sagebrush seed exposed to full light at 70° F. had the highest germination. Sagebrush seed germinated in the dark at 38° F. gave lower germination percentages than other treatments. However, a significant difference was not found between samples germinated in full light at 38° F. and those germinated in dark at 70° F. Exposure to light increased germination of sagebrush seed at a low temperature. It was found that in darkness at 70° F. germination of sagebrush seed was more than triple that in the dark at 38° F.

The amount of available moisture also influenced the germination of sagebrush seed. Osmotic solutions of 0, 4, and 8 atmospheres tension were used to limit the moisture available to the germinating seed. An increase in atmospheric tension resulted in a corresponding decrease in germination percentage. Lower germination of sagebrush seed was obtained as atmospheric tension was increased from 0 to 4 atmospheres and from 4 to 8. These decreases were significant at the 1 percent level of probability (Table 2).

The combined effect of temperature at 0, 4, and 8 atmospheres tension upon sagebrush seed germination was measured. At 38° F. the decrease in percentage germination brought about by increasing atmospheric tension from 0 to 4 atmospheres was significant, but increasing the atmospheric tension from 4 to 8 did not give a significantly lower germination percentage. The decrease in percentage germination as atmospheric tension was increased from 0 to 4 atmospheres and from 4 to 8 was found to be highly significant for the samples exposed at 70° F. As availability of water was decreased, seed germinated relatively better at 70° F. than they did at 38° F. It was found that samples germinated at 4 atmospheres and 70° F. were significantly higher than those germinated at 0 atmosphere and 38° F. The same was true of seed germinated at 8 atmospheres and 70° F. and of those germinated

Table 2. Average germination of sagebrush seed at three atmospheric tensions and two temperatures.

Temperature (°F)	Atmospheric tension		
	0	4	8
	Percent	*Percent*	*Percent*
38	14.2*	9.2	5.8
70	38.5	20.5	13 8
Average	26.4	14.8	9.8
Atmospheric tension LSD	.05	3.2	
	.01	4.4	
Atmospheric tension x temperature LSD		.05	4.5
		.01	6.3

* Each value is an average of four observations, two for each of the light conditions.

Table 3. Germination of sagebrush seed at two light intensities and three atmospheric tensions.

Light Intensity	Atmospheric tension		
	0	4	8
	percent	*percent*	*percent*
Dark	12.8*	8.5	4.0
Full light	40.6	21.2	15.5
Light x atmospheric tension LSD		.05	4.5
		.01	6.3

* Each value is an average of four observations, two for each of the temperatures.

at 4 atmospheres and 38° F. (Table 2).

Dark and full light had approximately the same effect as low or high temperature upon germination of sagebrush seed when moisture was limited to 0, 4, and 8 atmospheres tension. Germination in the dark was not significantly increased from 0 to 4 atmospheres, but increasing the atmospheric tension to 8 did give significantly lower germination percentages. When the seeds were germinated in full sunlight, each increase in atmospheric tension resulted in lower germination percentages (Table 3). As was true at 70° F., full light intensity partially alleviated a decrease in availability of moisture.

Grass and forb undercover are important when a sagebrush eradication program is initiated and then in maintaining a good under-story of vegetation to prevent sagebrush re-establishment. An overgrazed range relinquishes both moisture and sunlight to the sagebrush seed. Sunlight will result in higher temperature and a more suitable microclimate for sagebrush establishment.

Summary

Effects of light, temperature, and available moisture upon the germination of sagebrush seed were studied. The three environmental factors were combined at two levels each for light and temperature and three levels of available moisture giving a total of 12 different conditions tested. The following conclusions can be drawn:

1. Sagebrush seed exposed to light gave germination percentages three times as high as sagebrush seed germinated in the dark.
2. Sagebrush seed subjected to 70° F. resulted in a germination percentage double that obtained when sagebrush seed were subjected to a temperature of 38° F.
3. A reduction in available moisture substantially reduced the germination of sagebrush seed.
4. A temperature of 70° F. lessened the effect of darkness and low available moisture in reducing the germination of sagebrush seed.
5. Germination was highest at 70° F., with free moisture and full light.

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Pacific Southwest Forest and Range Experiment Station

Dedication ceremonies were held June 3 in Berkeley, California, for the Pacific Southwest Forest and Range Experiment Station. The new station was formerly known as the California Forest and Range Experiment Station and was housed in Mulford Hall at the University of California. The renamed research center is now in a new building at 1960 Addison Street.

KEITH ARNOLD, director of the station, presided at the ceremonies. Among the speakers were V. L. HARPER of Washington, D. C., assistant Chief of the Forest Service Branch of Research; DE WITT NELSON, director of the California Department of Natural Resources, Sacramento; T. R. YOCUM of the Simpson Timber Company, Seattle, Wash.; and DANIEL E. ALDRICH, dean of agriculture at the University of California.