Bitterbrush Seedling Establishment as Influenced by Soil Moisture and Soil Surface Temperature[1]

ROBERT B. FERGUSON[2]

Associate Wildlife Biologist, Intermountain Forest and Range Experiment Station, Forest Service, U. S. Department of Agriculture, Ogden, Utah.

Highlight

Bitterbrush seeds exposed to field conditions for 80 days following seed fall exhibited reduced viability. Exposure of seeds to dry heat for periods up to 15 consecutive hours in the laboratory did not reduce germination percentage until temperature exceeded 176 F. No evidence was found that high soil surface temperatures resulted in seedling mortality. Seedling survival and growth were significantly affected by both artificial watering and slope exposure.

Artificial revegetation is often the most rapid and practical way to restore or increase the supply of forage on mule deer (*Odocoileus hemionus*) winter range. In southern Idaho, as in other parts of the mountainous Western United States, bitterbrush (*Purshia tridentata* (Pursh) DC.) is one of the most valuable forage plants for use in revegetation efforts. Holmgren (1954) and Holmgren and Basile (1959) cited the value of this palatable shrub. Holmgren (1956) also pointed out that the mortality rate of bitterbrush seedlings often was high; Hormay (1943) stated that perhaps less than 5% of planted seed will produce mature plants.

The effects of available soil moisture, soil surface temperatures and air temperatures on establishment of bitterbrush seedlings have not been thoroughly assessed. Holmgren (1956) concluded that few bitterbrush seedlings are able to survive competition from cheatgrass (*Bromus tectorum* L.) and that the inhibiting influence of broad-leaved weeds results in stands of low-vigor plants, which continue to die off for 2 or 3 years. Hubbard (1956) noted that elimination of weed and grass competition greatly increased bitterbrush seedling growth and reduced seedling mortality.

Even when competing vegetation is eliminated within a 6.25 ft^2 plot around bitterbrush seedlings, as recommended by Holmgren and Basile (1959), I have observed 60 to 90% seedling mortality in some seeding trials. Such high mortality emphasizes the need to assess the influence of environmental factors on seedling survival.

In recent years, a research work unit at Boise, Idaho, of the Intermountain Forest and Range Experiment Station, Forest Service, U. S. Dept. of Agriculture, has continued research on factors affecting the successful establishment of bitterbrush by direct seeding. This paper presents the findings from several separate studies that clarify the influence of soil moisture and environmental temperatures on bitterbrush seedling establishment. These findings may increase our understanding of the factors affecting the natural establishment of bitterbrush seedlings.

Effects of Heat on Seed Viability

Bitterbrush seed ripens from late June through July on foothill ranges in most of southern Idaho. The seed falls to the surface of the soil and is exposed to environmental temperatures that are determined primarily by vegetative cover and by aspect and slope of terrain. I have measured temperatures as high as 168 F at the soil surface of a south-facing slope dominated by cheatgrass; temperatures between 140 and 160 F are common in the summer months. The question thus arises whether the hot microenvironment at the soil surface could be severe enough to lower seed viability.

In four separate experiments we exposed bitterbrush seeds to dry heat at oven temperatures ranging from 120 to 205 F. Periods of exposure ranged from 5 to 15 hours. Table 1 shows the temperature treatments to which seeds were exposed and the number of seeds used in each experiment.

Exposure of seeds to dry heat in the laboratory did not result in a significant reduction in germination percentage until temperatures exceeded 176 F. Thus it seemed that environmental temperatures to which bitterbrush seeds are normally exposed under field conditions do not have a major effect on seed viability.

However, a later field experiment indicated that some seeds may be damaged as a result of exposure to conditions existing on the soil surface following seed fall. Bitterbrush seeds were collected in early July 1966. Half the seeds were immediately scattered on a bared south-facing soil surface. The remaining seeds were stored at room temperature. After 80 days, the field-exposed seeds were retrieved. Seed dormancy was broken by thiourea treatment (Pearson, 1957; Hubbard et al., 1959) and the seeds tested for germination at room temperature. Mean percent germination was 78 and 82 for two replications (400 seeds in each) of field-exposed seeds, and 92 for both replications of laboratory-stored seeds.

A smaller sample of the seeds from each group was examined following staining with tetrazolium chloride. This method of assessing viability (Moore, 1960) indicated that 84% of 45 field-exposed seeds were viable, whereas all 49 seeds in the lab-stored sample were judged viable. Inasmuch as the results of the germination and the tetrazolium tests were similar, there is

[1] Information reported here was obtained through cooperation of the Intermountain Forest and Range Experiment Station and the Idaho Fish and Game Department, Federal Aid in Wildlife Restoration Project W-111-R. Received March 6, 1971.

[2] Stationed in Boise, Idaho.

Table 1. Dry heat (°F) treatments[1] applied to bitterbrush seed in four separate laboratory experiments.

Experiment no.	Treatments: Oven temperature	Length of exposure (hr)	No. seeds per treatment	Replications
1	130, 145, 160	5, 10, 15	100	4
2	130, 160, 190	5	50	8
3	160, 175, 190, 205, 220	5	100	4
4	120, 140, 160, 175, 195	5	100	4

[1] In each experiment, seed that had been exposed to room temperature only were used as a check.

little doubt that some seeds exposed to field conditions were damaged. Prolonged desiccation is suspect, although such factors as disease or fungi cannot be ruled out.

Soil Moisture and Environmental Temperature

Bitterbrush seed will begin germination during the winter months. The cotyledons of the seedling may emerge at any time from late February through late April depending on the rate of soil warming.

Throughout southern Idaho (especially on areas of granitic soils), bitterbrush seedlings seldom survive except where competing vegetation is sparse or almost completely lacking within a radius of 1 to 3 feet of the seedling. Establishment by direct seeding requires site preparation that will free emerging seedlings from competition for available soil moisture. The importance of this is born out by data collected during the summers of 1965 and 1966.

In the early spring of 1965, sixty 5-gallon cardboard containers were filled with granitic topsoil. The soil was thoroughly mixed, and exactly the same amount packed into each container. Several small holes were made in the bottom of each container for drainage. Twelve containers of seedlings were set flush with the soil surface at each of five exposures (NE, E, SE, SW, W) around a cone-shaped hill. The study area was 10 miles east of Boise, Idaho. In April 1965, four seedlings were established in each container (the number was changed to three in 1966). The same containers were used in both years, having been left in place during the winter of 1965–66. Half the containers on each aspect were provided with periodic subsurface irrigation throughout the growing season. During the period June 1 to September 30, data on seedling survival and rate of growth were recorded at regular intervals. Maximum soil surface temperatures reached on each exposure were recorded at least once each week using thermopapers. In both years, the 10- by 20-ft rectangular plots within which the 12 containers of seedlings were located were kept free of all vegetation.

Effect of Supplemental Water on Survival and Growth

Survival and mean seedling weights at the end of each growing season are shown in Table 2. Analysis of variance indicated that survival of watered seedlings was significantly better ($P < .05$) than that of unwatered seedlings in both years. Similarly, in both years, watered seedlings were significantly heavier ($P < .01$) than unwatered seedlings.

Monthly measurements of seedling height showed that virtually all surviving seedlings continued growing throughout each summer. Thus, with the elimination of competing vegetation, even unwatered seedlings were able to withdraw sufficient water from the soil to continue growth. This was notably demonstrated in 1966 when the cumulative precipitation from October 1, 1965, through May 31, 1966, at a weather station 4 miles to the east was 10.4 inches, the second-driest such period in 54 years.

Effect of Exposure on Survival and Growth

Only in 1965 was there a statistically significant difference ($P < .05$) in survival among exposures. The

Table 2. Comparison of survival (%) and mean weight (g) of watered and nonwatered bitterbrush seedlings on five aspects. Mores Creek study area, 1965 and 1966.

Aspect and treatment	1965 Survival	1965 Mean weight	1966 Survival	1966 Mean weight
NE				
Watered	88 (21/24)	5.50	100 (18/18)	7.58
Unwatered	84 (16/19)	3.48	89 (16/18)	4.50
ESE				
Watered	96 (23/24)	7.17	94 (17/18)	11.11
Unwatered	88 (21/24)	3.65	78 (14/18)	6.26
SSE				
Watered	83 (20/23)	6.00	100 (18/18)	6.62
Unwatered	52 (12/23)	4.40	78 (14/18)	2.66
SW				
Watered	46 (11/24)	1.89	78 (14/18)	4.77
Unwatered	22 (6/23)	1.41	78 (14/18)	2.27
W				
Watered	96 (23/24)	4.59	72 (13/18)	9.77
Unwatered	75 (18/24)	4.02	61 (11/18)	4.47

difference in that year was due to the poorer survival on the southwest exposure.

Significant differences (< .01) in growth occurred on the several exposures during both years. The heaviest seedlings grew on the southeast exposures, especially when they received supplemental water. In both years the southwest exposure produced the smallest seedlings.

Soil Surface and Air Temperatures

Careful examination of many seedlings under field conditions indicates that bitterbrush seedlings can endure extremely high soil surface temperatures. In southern Idaho, a soil surface temperature of 140 F may be reached at any time between approximately May 1 and October 1 when the maximum daily air temperature reaches 90 F and night temperatures are higher than 50 F. During June and much of July, soil surface temperatures of 150 F or higher often occur on south-facing slopes.

Despite careful examination of numerous seedlings, we have yet to find a definite stem lesion caused by high temperature such as those described for coniferous species by Baker (1929), Vaartaja (1954), Silen (1960), Shearer (1967), and others. However, in tests made in the greenhouse we have produced complete girdling of the stem and the subsequent death of the seedling by artificially heating the soil surface to 140–150 F with a magnifying glass. This result can be obtained after 2 to 5 minutes exposure to heated soil.

It is probable that field-grown seedlings become hardened to high soil surface temperatures. Otherwise, it would be difficult to account for the survival of many seedlings growing where soil surface temperatures above 130 F commonly last for periods of 3 to 5 hours on clear, hot days. Greenhouse-grown seedlings girdled by heating the soil surface may remain alive for as long as 3 weeks. We used orthotolidine solution to test for the viability of stem and root tissue and found that the root below the heat-damaged area remained alive for some time after the death of the top.

Some of the seedlings observed during the summers of 1965 and 1966 died from undetermined causes. While disease or root damage by some soil-inhabiting organism may have caused these losses, it is possible that excessively high air temperatures were responsible. Twice-weekly readings of maximum registering thermometers placed at 1 and 2 inches above the soil revealed that air temperatures between 110 and 120 F were quite common. Slow-growing seedlings with most of their leaves in the air layer near the soil surface are thus exposed to extremely desiccating conditions.

Implications for Seeding Success

Our studies indicate that soil moisture has a significant effect on the vigor and growth of bitterbrush seedlings. Although the drier conditions usually encountered on southwest exposures tend to overcome all but the most vigorous seedlings, satisfactory seedling survival can be obtained if special care is taken to eliminate competing vegetation prior to seeding. Handmade scalps intended to control vegetative competition should be at least 30 inches square, as recommended by Holmgren and Basile (1959). My own observations lead me to believe that scalps are even more effective when made 3 feet square. Scalped strips made with a bulldozer are effective and should be 3 to 4 feet wide.

Evidence also indicates that when other site factors are approximately equal, seedling growth is somewhat more rapid on south-easterly slopes than other exposures. Where a choice can be made, or when revegetation efforts are limited by availability of seed, nursery stock, or lack of funds, it would perhaps be wise to utilize the southeast exposures as often as possible.

Literature Cited

Baker, F. S. 1929. Effect of excessively high temperatures on coniferous reproduction. J. Forest. 27:949–975.

Holmgren, R. C. 1954. A comparison of browse species for revegetation of big-game winter ranges in southwestern Idaho. U. S. Forest Serv., Intermountain Forest & Range Exp. Sta. Res. Pap. 33, 12 p.

Holmgren, R. C. 1956. Competition between annuals and young bitterbrush (*Purshia tridentata*) in Idaho. Ecology 37:370–377.

Holmgren, R. C., and J. V. Basile. 1959. Improving southern Idaho deer winter ranges by artificial revegetation. State of Idaho, Dep. Fish & Game Wildl. Bull. 3, 61 p.

Hormay, A. L. 1943. Bitterbrush in California. U. S. Forest Serv., Calif. Forest & Range Exp. Sta. Res. Note 34, 4 p.

Hubbard, R. L. 1956. The effects of plant competition upon the growth and survival of bitterbrush seedlings. U. S. Forest Serv., Pacific Southwest Forest & Range Exp. Sta. Res. Note 109, 9 p.

Hubbard, R. L., E. C. Nord, and L. L. Brown. 1959. Bitterbrush reseeding —a tool for the game range manager. U. S. Forest Serv., Pacific Southwest Forest & Range Exp. Sta. Misc. Pap. 39, 14 p.

Moore, R. P. 1960. Tetrazolium testing techniques. p. 45–51 in: 38th Annual Meeting, Soc. Com. Seed Technologist Proc.

Pearson, B. O. 1957. Bitterbrush seed dormancy broken with thiourea. J. Range Manage. 10:41–42.

Shearer, R. C. 1967. Insolation limits initial establishment of western larch seedlings. U. S. Forest Serv. Res. Note INT-64, 8 p.

Silen, R. R. 1960. Lethal surface temperatures and their interpretation for Douglas-fir. Ph.D. Diss. Ore. State Coll., Corvallis, Ore. 170 p.

Vaartaja, O. 1954. Factors causing mortality of tree seeds and succulent seedlings. Acta Forestalia Fennica 62, 31 p.