# Arrowleaf Balsamroot and Mules Ear Seed Germination

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**Abstract**

**The germination of arrowleaf balsamroot (*Balsamorhiza sagittata*) and mules ear (*Wyethia amplexicaulis*) was studied. Both species are important coarse forbs on sagebrush (*Artemisia*) rangelands in western North America. Germination of the seeds (achenes) of both species was enhanced by cool-moist stratification, 4 weeks at 2 or 5° C for mules ear and 12 weeks for arrowleaf balsamroot. After stratification, mules ear seeds germinated at a wide range of constant and alternating temperatures. Germination of arrowleaf balsamroot seeds was greatly enhanced by stratification, but even after stratification, germination was restricted to comparatively low temperatures.**

Arrowleaf balsamroot (*Balsamorhiza sigittata*) and mules ear (*Wyethia amplexicaulis*) are both robust, tap-rooted perennial forbs with large, usually solitary, flower heads. The ray flowers are showy, and usually yellow. Other than historical practice, there probably is no reason to treat *Wyethia* and *Balsamorhiza* as separate genera (Cronquist 1955). Both genera are widely distributed from the Pacific Northwest to Nevada and east to Colorado. There are apparently few barriers to hybridization among species of either genus (Cronquist 1955). Numerous hybrids have been identified in local areas.

Both arrowleaf balsamroot and mules ear have wide ecologic distribution in numerous plant communities (Anonymous 1937). However, both species are most abundant in the more mesic sagebrush (*Artemisia*) grasslands. These are the sites at higher elevations and north-facing slopes where more moisture is available for plant growth. Both species are also common in woodland or seral timber communities at elevations above the sagebrush zone. Densities of arrowleaf balsamroot and mules ear generally increase after range communities are burned (Young and Evans 1977). This increase is especially evident if degraded plant communities are burned. In some areas where these coarse forbs have greatly increased, they represent serious competition for forage grasses and other forbs (Young and Evans 1978).

Young basal leaves of these species are springly grazed by livestock. Arrowleaf balsamroot generally grows in mixed stands with grasses, other forbs, and shrubs. Mules ear is generally less preferred as forage and it grows to the exclusion of other, more desirable forage species. Mature herbage is generally too coarse for use by livestock. Cattle, sheep, and horses will graze on the flower heads and, in years with good seed production, livestock will eat the seeds.

Reproduction of these two species is entirely by seeds and species increase at the expense of forage grasses. With their attractive and showy flowers, both arrowleaf balsamroot and mules ear may be desirable revegetation species for mining spoils and other disturbed areas where they are adapted. A knowledge of seed germination and seedbed ecology is necessary for successful revegetation with these species.

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Our purpose in this investigation was to investigate the germination of these two species.

## Methods

Seeds of mules ear and arrowleaf balsamroot were collected from numerous stands in northern Nevada and northeastern California from 1970 through 1976. Seeds from numerous plants at each location were composited in a single collection for each species. Preliminary trials showed that most seeds of both species were dormant and that this dormancy was not broken with dry storage. These trials also showed that dormancy could be broken with cool-moist stratification.

Using results of the preliminary trials, a comprehensive stratification experiment was designed. Seeds for each species from two different sources were used, and the results were averaged for presentation. Four replications of 100 seeds were used in each experiment. Cellulose was used instead of sand or vermiculite as the stratification medium so that the seeds could be easily observed during the stratification period. Seeds were placed on a single thickness of expanded cellulose in petri dishes, and the dishes were covered with a single thickness of germination paper for stratification. The paper and cellulose were kept moist during the entire stratification period. Stratification treatments were at 0, 2, 5, and 10°C in dark germinators for 2, 4, 6, 8, 10, and 12 weeks. At the end of each stratification period seeds were removed and incubated for 4 weeks at 10/25°C (10°C for 16 hr and 25°C for 8 hr daily) for mules ear and at 10°C for arrowleaf balsamroot. Results of preliminary trials indicated that these temperatures were optimaly effective, with optimum effectiveness defined as not being significantly ($P=0.05$) different from maximum germination. Germination counts were made after 1, 2, and 4 weeks of incubation. Seeds were considered to have germinated when the radicle had emerged 1 cm.

Temperature profiles were developed for pretreated (stratified) and unstratified seeds of each species. To develop germination profiles as affected by temperature, we incubated seeds of both species for 4 weeks at constant temperatures of 0, 2, 5, 10, 15, 20, 25, 30, 35, and 40°C. In addition, seeds were incubated at each of these constant temperatures for 16 hr in alternation with each possible higher temperature for 8 hr in each 24 hr period. For example, 0°C was alternated with 2, 5, 10, 15, 20, 25, 30, 35, and 40°C wheras 35°C was alternated with 40°C only.

## Results and Discussion

The germination of seeds of both mules ear and arrowleaf balsamroot was enhanced by cool-moist stratification to break dormancy. Other than this generalization, there was little resemblance in the germination characteristics of the two species.

### Mules Ear

Some seeds of mules ear germinated without stratification (Table 1). However, cool-moist stratification greatly enhanced their germination. Stratification of mules ear seeds for 4 weeks was required for near maximum germination (Fig. 1). Temperatures of 2 to 5°C were required. Microbial decomposition prevented germination of mules ear seeds after 8 weeks of stratification at 10°C. This temperature never resulted in enhancement of germination. At the other extreme, stratification at 0°C never enhanced germination and resulted in a slow decline in germinability.

Nonstratified seeds of mules ear germinated in about one-half of the 55 constant-and alternating temperature regimes tested (Table 1). When seeds were stratified at 2°C for 4 weeks and then exposed to the same temperature regimes, some germination occurred at all temperatures but a constant 0°C.

There were three optimum alternating temperature regimes for nonstratified and five optima for stratified mules ear seeds (Table 1). Three of the optima, 5/20, 5/25, and 5/30°C, were the same for each treatment. The additional optima for stratified seeds, were 10/25 and 10/30°C. Although the optima occurred in the same general range of alternating temperatures, the magnitude of germination at the optima differed greatly between nonstratified and stratified seeds. The mean germination at the optimum temperatures was 45% for nonstratified

**Table 1. Germination (%) of mules ear seeds at constant and alternating temperatures with and without previous moist stratification. Incubation for 4 weeks.[1]**

| | Cool period °C−16 hr | Warm period °C−8 hr. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0 | 2 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
| Germination after 4 weeks stratification at 2°C | 0 | 0 | 4q-s | 9p-s | 7q-s | 18l-s | 20j-s | 24j-r | 20k-s | 15m-s | 6q-s |
| | 2 | | 7q-s | 10o-s | 26j-r | 41f-j | 23j-s | 65c-e | 68b-e | 36h-n | 15m-s |
| | 5 | | | 16m-s | 32i-n | 61c-f | 76a-d | 81a-c | 92a | 30j-o | 16m-s |
| | 10 | | | | 31j-n | 54e-h | 66c-e | 94a | 88ab | 24j-r | 28j-p |
| | 15 | | | | | 24j-r | 30k-n | 68b-e | 58d-g | 40f-k | 11n-s |
| | 20 | | | | | | 16m-s | 53e-i | 42f-j | 20k-s | 8p-s |
| | 25 | | | | | | | 38g-l | 22j-s | 14n-s | 2s |
| | 30 | | | | | | | | 5q-s | 9p-s | 4q-s |
| | 35 | | | | | | | | | 4q-s | 2s |
| | 40 | | | | | | | | | | 3r-s |
| Germination with unstratified seed | 0 | 0 | 0 | 0 | 0 | 2g | 26b-f | 9e-g | 4g | 0 | 0 |
| | 2 | | 0 | 0 | 2g | 13d-s | 29b-e | 31b-d | 24c-g | 0 | 0 |
| | 5 | | | 1g | 5g | 15d-g | 45ab | 52ab | 39a-c | 0 | 0 |
| | 10 | | | | 5g | 11e-g | 16d-g | 27b-f | 19d-g | 0 | 0 |
| | 15 | | | | | 13d-g | 13d-g | 16d-g | 15d-g | 0 | 0 |
| | 20 | | | | | | 3g | 8f-g | 3g | 0 | 0 |
| | 25 | | | | | | | 0 | 0 | 0 | |
| | 30 | | | | | | | | 0 | 0 | 0 |
| | 35 | | | | | | | | | 0 | 0 |
| | 40 | | | | | | | | | | 0 |

All means followed by the same letters are not significantly different at the 0.01 level of probability as determined by Duncan's multiple range test stratification and control compared separately. For readers' convenience, means not significantly different from maximum are underlined.

**Table 2. Germination (%) of arrowleaf balsamroot seed at constant and alternating temperatures with and without previous moist stratifications incubation for 4 weeks.[1]**

| | Cool period °C – 16 hr | Warm period °C – 8 hr 0 | 2 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Germination after 4 weeks stratification at 2° C | 0 | 6m-o | 2 0j-o | 69a-e | 68a-e | 76a-c | 72a-d | 47e-i | 28i-m | 0 | 0 |
| | 2 | | 36g-k | 80ab | 67a-e | 69a-e | 43f-j | 27i-n | 30i-l | 15k-o | 0 |
| | 5 | | | 87a | 86ab | 65a-f | 57b-h | 43f-j | 50d-i | 3 0 | 0 |
| | 10 | | | | 69a-e | 34i-k | 43f-j | 35h-k | 21j-o | 3 0 | 0 |
| | 15 | | | | | 36g-k | 20j-o | 8L-O | 19k-o | 0 | 0 |
| | 20 | | | | | | 27i-n | 9L-O | 6m-o | 0 | 0 |
| | 25 | | | | | | | 4no | 3o | 1o | 0 |
| | 30 | | | | | | | | 6m-o | 0 | 0 |
| | 35 | | | | | | | | | 0 | 0 |
| | 40 | | | | | | | | | | 0 |
| Germination with unstratified seed | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| | 2 | | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 |
| | 5 | | | 4 | 0 | 2 | 8 | 0 | 0 | 0 | |
| | 10 | | | | 18 | 2 | 0 | 4 | 0 | 0 | 0 |
| | 15 | | | | | 0 | 0 | 0 | 0 | 0 | 0 |
| | 20 | | | | | | 0 | 0 | 0 | 0 | 0 |
| | 25 | | | | | | | 0 | 0 | 0 | 0 |
| | 30 | | | | | | | | 0 | 0 | 0 |
| | 35 | | | | | | | | | 0 | 0 |
| | 40 | | | | | | | | | | 0 |

[1] All means of stratified seed followed by the same letters are not significantly different at the 0.01 level of probability as determined by Duncan's multiple range test. For reader's convenience, means not significantly different from maximum are underlined.

seeds and 86% for stratified seeds.

Without stratification, mules ear seeds did not germinate with cool-period temperatures higher than 20°C or warm-period temperatures higher than 30°C. Alternation with extremes of low temperatures also inhibited germination.

With stratification, none of the temperature regimes tested prevented germination of mules ear seeds except a constant 0°C, but germination tended to be quite low at extremes of high and low temperatures.

**Arrowleaf Balsamroot**

For seeds of arrowleaf balsamroot, in contrast to the seeds of mules ear, germination without stratification was very low and erratic (Table 2). A 12 week period of stratification was required for enhancement of germination and for maximum germination (Fig. 2).

As with mules ear seeds, the highest stratification temperature tested (10°C) was not effective, and the most effective temperatures were 2 and 5°C. At the lowest temperature (0°), stratification for 12 weeks was required for enhancement of germination (Fig. 2).

Stratification for 8 weeks at 5°C was the pretreatment used for development of the temperatures for arrowleaf balsamroot profile. We chose 8 weeks, even though germination after this stratification period was only 50% of that obtained after 12

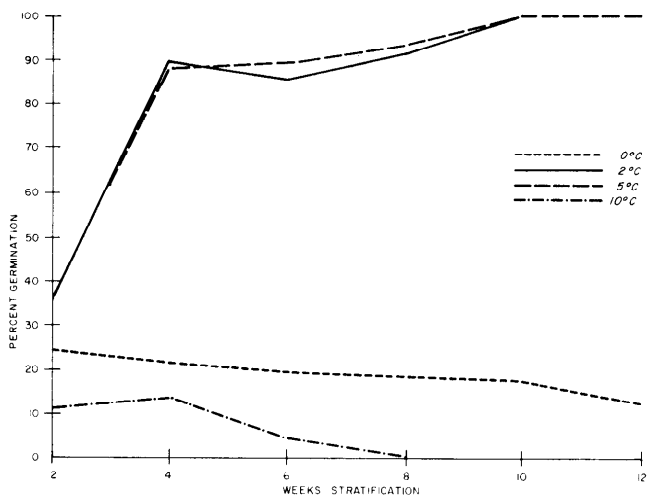


**Fig. 1.** *Germination (%) of mules ear seeds after moist stratification at 0, 2, 5, or 10°C from 2 through 12 weeks. Seeds were then incubated at 10/25°C (10°C for 16 hr/25°C for 18 hr daily) for weeks before germination percentages were determined.*

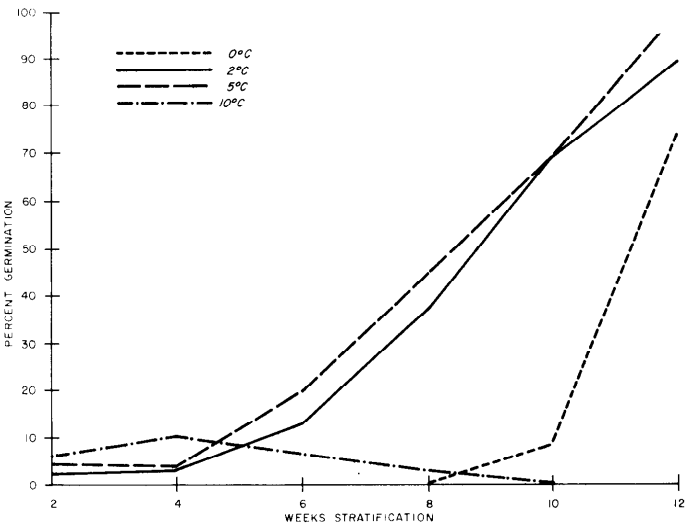


**Fig. 2.** *Germination (%) of arrowleaf balsamroot seeds after moist stratification at 0, 2, 5, or 10°C from 2 through 12 weeks. Seeds were then incubated at 10°C for 4 weeks before germination percentages were determined.*

weeks of stratification, because some seeds germinated during stratification. The problem is that optimum temperatures for germination were essentially temperatures for the optimum stratification. This complicates stratification of arrowleaf balsamroot seeds before sowing in the field or nursery, because of the danger that emerging radicles will be damaged.

Nonstratified arrowleaf balsamroot seeds germinated at only 15% of the temperature regimes tested (Table 2). Stratified seeds germinated at 55% of the temperature regimes.

There were no significant differences among germination percentages for nonstratified seeds. In contrast, 11 temperature regimes were optima for germination of stratified seeds (Table 2). The warmest of these regimes was a constant 10°C and the coldest was 0/5°C. All of the optima temperatures were very low for germination in comparison with optima for other species. A temperature of 35°C reduced germination and a warm-period temperature of 40°C prevented germination.

### Significance of Stratification Requirements

Although stratification is essential for the germination of many seeds of species in such economically important families a Rosaceae, Juglandaceae, and Pinaceae, we do not know by what processes stratification affects germination. Come and Tissaoui (1972) provided an enlightening discussion on the probable mode of action of cool-moist stratification in transferring oxygen to dormant embryos through restrictive seedcoats.

In a previous study (Young and Evans 1977) we found that for seed of bitterbrush (*Purshia tridentata*) cool-moist stratification requirements may be extended if stratification is interrupted by varying temperatures or moisture stress. Seeds of mules ear require only 4 weeks of stratification, so a cool-moist period in the fall could satisfy the stratification requirement. However, we must remember that stratification temperature must remain above 0°C and below 10°C for best germination of mules ear seeds.

The 3-month stratification requirement of arrowleaf balsamroot seeds is long for many rangeland seedbed, even through 0°C appears to be an acceptable stratification temperature for this species. The 0°C environment we used for stratification did not crystalize the water. In other studies (Young and Evans 1977), we have shown that in species in which germination is enhanced by stratification at 0°C, exposure to −2°C reduces or prevents the enhancement; i.e., the range of acceptable temperatures is very restricted. The only environment on sagebrush rangelands that might have a satisfactory stratification of arrowleaf balsamroot seeds is at the snow-litter-soil interface in sites with continuous snow cover for at least 3 months. This may explain the occurrence of dense communities of arrowleaf balsamroot on north-facing slopes where snow drifts accumulate. The snow-soil interface as a germination environment has been studied by Bleak (1959) and Hull (1960).

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