Sagebrush Reinvasion as Affected by some Environmental Influences[1]

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Highlight

Five chemically sprayed and 15 plowed and seeded areas in southwestern Montana were examined to determine the influence of several environmental factors on big sagebrush reinvasion. Sagebrush surviving the treatments was found to be the most important factor related to reinvasion. Plowing near or after sagebrush seed maturation resulted in heavy reinfestation of seeded stands. Sagebrush adjacent to treated areas was of no practical importance as a seed source for reinvasion. Non-sagebrush vegetation, slope, erosion, soil texture, and precipitation were seldom related to sagebrush reinvasion. Northwest exposures favored reinvasion.

Large acreages of big sagebrush (*Artemisia tridentata*) have been treated by various control methods in the Intermountain region. Successful reduction of sagebrush densities has resulted in increased grass production. Two common methods of sagebrush removal are chemical spraying and plowing. Spraying has the advantage of not disturbing the soil but is successful only when ample desirable grasses are present to assume dominance. Plowing usually requires seeding. Unfortunately, big sagebrush reinvades many treated areas.

Observers generally agree that intensive grazing has resulted in increased density and distribution of sagebrush (Lommasson, 1946; Frischknecht and Plummer, 1955; and others).

Beneficial results of control measures are often temporary due to rapid reinvasion following initial stand reductions (Lommasson, 1947; Bleak and Miller, 1955; Frischknecht and Plummer, 1955; and others).

Seed source is the primary question in sagebrush re-establishment. Mueggler (1956) concluded that wind-borne seed was restricted to within a few hundred feet of the treatment edges, and that residual seed was the greater source for reinvasion on burned areas in Idaho. The maximum distance of seed dissemination by wind was found to be about 33 m by Goodwin (1956) who also indicated that morphological characteristics of sagebrush seed allowed adherence to passing objects upon contact. Frischknecht and Plummer (1955) stated that seed was transported to a 45-acre site by wind and to some extent by animals. Lommasson (1946) and Bleak and Miller (1955) concluded that sagebrush reinvasion resulted from seed produced by plants surviving eradication.

Sagebrush seed production and subsequent potential re-establishment vary with date of mechanical eradication. Bleak and Miller (1955) found spring eradication resulted in low sagebrush kills with the remaining plants becoming prolific seed producers. Pechanec et al. (1944) and Bleak and Miller (1955) stated that fall eradication after seed set scattered the seed and prepared a good seed bed.

Many studies have concluded that seeded grass stands cannot become established unless the competitive effects of mature sagebrush are reduced (Pechanec et al., 1944; Blaisdell, 1949). Once perennial grasses are established, however, young sagebrush seedlings tend to become excluded (Pechanec et al., 1944). Beetle (1960) observed that grasses were more likely to establish when a litter layer was present than were sagebrush seedlings. Robertson (1947) reported mature sagebrush plants contributed to sagebrush seedling establishment since the areas under the shrubs were void of grasses.

Years favorable for natural sagebrush seedling establishment come at irregular intervals (Blaisdell, 1949). Bleak and Miller (1955) stated that available moisture was a primary factor. Lommasson (1946, 1947) found that above normal precipitation during the year of establishment as well as in following years enhanced seedling survival. Opposing this, Beetle (1960) stated drought gave an advantage to sagebrush seedlings, whereas adequate moisture was advantageous to grasses.

To shed further light on the problem of reinvasion, the following environmental and biological factors were examined on 20 treated areas in southwestern Montana: (1) effectiveness of initial sagebrush kill; (2) time of treatment in relation to sagebrush maturity; (3) influence of wind-borne seed; (4) competition with non-sagebrush vegetation; (5) yearly precipitation regimes; and (6) surface soil texture, erosion class, slope, and exposure.

Experimental Area and Procedure

Field research was conducted in southwestern Montana, mostly within 50 air miles of Dillon. Fifteen plowed and

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Table 1. Average number of sagebrush per square meter in 5 sprayed areas and 15 plowed and seeded areas, Beaverhead County, Montana, 1965. Earliest year of sagebrush establishment for each location is the first growing season following eradication. Reinvaded sagebrush are listed by year of establishment.

Location	Sagebrush plants present in 1965 by year of establishment									Plants surviving eradication[1]	Total plants[1]	Total plants estab. after treatment[1]	Total plants less 1965 establishment[1]	Total plants estab. after treatment less 1965 establishment[1]
	1957	1958	1959	1960	1961	1962	1963	1964	1965					
Sprayed areas														
Coyote Flats			0.3	0.2	0.5	0.2	1.2	1.8	6.5	0.2	10.8	10.7	4.4	4.2
Reservoir Creek						T	T	T	0.3	0.1	0.5	0.4	0.2	0.1
Muddy Creek								0.4	0.4	0.2	1.0	0.8	0.6	0.4
Badger Pass								0.2	0.6	0.2	1.0	0.8	0.4	0.2
Bannack								0.1	0.1	0.3	0.6	0.2	0.3	0.1
Plowed & seeded areas														
Coyote Flat	2.3	0.5	0.5	0.3	0.2	0.1	T	T	0.1	0.1	5.3	5.2	5.2	5.1
PHW	1.8	0.5	0.7	0.4	0.4	0.1	0.2	0.9	1.1	0.3	6.3	6.0	5.2	4.9
Exchange		T	T	0.0	T	T	T	T	T	0.2	0.3	0.2	0.3	0.1
Hughes		0.1	0.0	T	T	T	T	0.1	0.1	0.2	0.5	0.4	0.4	0.3
Brenner			T	T	T	T	T	0.0	T	0.1	0.2	0.1	0.2	0.1
Mansfield			0.3	T	T	T	T	T	0.4	0.2	1.0	0.8	0.6	0.4
Rape Creek				0.1	T	0.1	0.3	0.4	0.8	0.3	1.9	1.7	1.1	0.8
Chinatown					T	T	1.1	1.6	4.2	0.2	7.1	6.9	2.8	2.7
Holland						T	0.1	0.2	3.8	0.3	4.4	4.1	0.6	0.3
Marchesseau						0.3	0.4	0.9	11.9	0.6	14.1	13.5	2.1	1.6
Junction							0.1	0.1	0.2	0.2	0.6	0.4	0.4	0.2
Rock Creek							0.3	0.2	1.1	0.3	2.0	1.6	0.9	0.5
Taylor Creek							T	T	8.3	0.3	8.6	8.3	0.3	T
Cottonwood Creek									3.8	0.4	4.2	3.8	0.4	0.0
Trail Creek									0.4	0.7	1.1	0.4	0.7	0.0

[1] Apparent discrepancies due to rounding error.
"T" = 0.01 to 0.05 plants per square meter.

seeded locations and five sprayed locations, totaling 28,681 acres were examined in 1965. Treatment dates were from 1957 to 1964.

Most sprayed areas occupy steeply rolling to mountainous foothill sites whereas the plowed areas are on gentler topography. The upland soils are mostly Aridisols (Brown, Solochak, and Solonetz) and Mollisols (Chestnut and Chernozem). The normally calcareous soils have A and B horizons with diverse depth and physical characteristics. Calcium carbonate deposits on upturned stones indicate shallow moisture penetration.

Over a 15-year period, precipitation at the Dillon airport ranged from 6.55 to 12.35, with an average of 9.59 inches. April, May, and June received over 50% of the annual precipitation. Isothermal lines drawn in 1961 indicate that most of the experimental sites are in the 8 to 12 inch annual precipitation zone. The growing season averages 88 days. The wide climatic extremes often are intensified by wind and exposure.

The native vegetation near the study areas is dominated by a big sagebrush—bluebunch wheatgrass (*Agropyron spicatum*) aspect. Associated shrubs are rabbitbrush (*Chrysothamnus* spp.) and three-tip sagebrush (*Artemisia tripartita*). Associated perennial grasses include Idaho fescue (*Festuca idahoensis*), Sandberg bluegrass (*Poa secunda*), needleandthread (*Stipa comata*), Indian ricegrass (*Oryzopsis hymenoides*), and western wheatgrass (*Agropyron smithii*). The most common forbs are the mat-type phlox (*Phlox* spp.) and lupines (*Lupinus* spp.).

Paired plots were placed at predetermined regular intervals along transects 150 m in length and at least 50 m apart. Transects used to test whether reinvasion came from outside the areas were designated "regression transects," and originated at and perpendicular to treatment edges with potential sagebrush seed sources. Other transects located within the treatment area were designated "interior transects."

Two types of plots (hence the term "paired plots") were used in sampling. One plot was one meter square and the other was circular with a radius of one meter, both with the same center.

All sagebrush plants within the square-meter plot were counted and aged by ring counts (Ferguson, 1964). Sagebrush plants established before the treatment within the circular plot were counted and designated as mature plants capable of seed production even though some were not producing seed at the time of the study. Mature plants were counted when foliage was present within the vertical projection of the circular plot boundaries.

Each pair of plots (for both regression and interior transects) had the following information recorded: surface soil texture (Dyksterhuis, 1964); direction of land exposure, with eight exposure classes; slope as determined with a hand level; and one of five erosion classes ranging from "none," with no soil movement and a vegetational litter cover of 80% within the square plot, to "severe rill," the precursor of active gullying. Basal cover of vegetation by

Table 2. Correlation coefficients between mature (treatment surviving) sagebrush and various age classes of reinvaded sagebrush.

Location	Associated degrees of freedom	Year in which reinvaded sagebrush became established									
		1957	1958	1959	1960	1961	1962	1963	1964	1965	Sum
Sprayed areas											
Coyote Flats	110			.248**	.092	.048	–.009	.039	.107	.021	.064
Reservoir Creek	615						.362**	.002	.096	.072	.090
Muddy Creek	305								.420**	.266**	.379**
Badger Pass	225								.483**	.284**	.382**
Bannack	225								.006	.084	.043
Plowed and seeded areas											
Coyote Flat	445	.089*	.088	.062	.052	.046	.333**	.055	–.033	.028	.124**
PHW	185	–.152*	.031	.067	.018	.185**	.105	.030	.157*	.140*	.139*
Exchange	380		.255**	.115*	.064	.051	.096	.097	.153**	.072	.200**
Hughes	265		.028	.000	.090	.069	.127*	.267**	.172*	.148*	.276**
Brenner	265			.065	–.021	.034	.076	.142*	.139*	.093	.164*
Mansfield	730			.005	.075	.111**	.086*	.148**	.106**	.148**	.172**
Rape Creek	300				.104	.053	.150**	.205**	.239**	.338**	.330**
Chinatown	570					.031	.090*	.166**	.253**	.368**	.367**
Holland	545						.334**	.351**	.194**	.151**	.184**
Marchesseau	480						.172**	.132**	.032	.214**	.216**
Junction	265							.180**	.152**	.038	.097
Rock Creek	185							.154*	.141*	.206**	.233**
Taylor Creek	550							.275**	.112**	.380**	.383**
Cottonwood Creek	225									.160*	.160*
Trail Creek	300									.120*	.120*

** Indicates significance at the 1% level.
* Indicates significance at the 5% level.

species was recorded along one edge of the meter square plot frame.

Field data were recorded on Port-a-punch cards and transferred to standard 80-column IBM cards. Standard mathematical and statistical procedures were used to evaluate the results.

Results and Discussion

Sagebrush age classes are shown in Table 1. From 0.1 to 0.7 sagebrush plants/m^2 survived the eradication treatments. There was no statistically significant difference between survival on areas that were sprayed and on areas that were plowed and seeded to grass.

Sagebrush plants established following sagebrush control activities varied widely among and within locations (Table 1). With few exceptions, there were more seedlings of 1965 germination (the year of the study) than any other year. This indicates a marked mortality of new seedlings before the second growing season. The column titled, "Total Plants Less 1965 Establishment" gives the best estimate of the number of sagebrush plants which may be expected to remain in an area. The last column, "Total Plants Established after Treatment, Less 1965 Establishment," is the best estimate of re-establishment of sagebrush.

Effectiveness of Initial Sagebrush Kill.—Re-established brush was found in association with mature brush in all but one of the treatment areas (Table 2). In 13 of the 20 locations, seedlings germinating in 1965 were significantly correlated with the mature brush, although the correlations were fairly low. Sagebrush plants germinating in 1964 likewise were significantly correlated with mature sagebrush in 13 of the 20 locations. Ten of these locations were the same as those having significant correlations for the 1965 seedlings. Ten locations had significant correlations for plants germinating in 1963 and eight for plants germinating in 1962. Plants germinating in earlier years showed few significant correlations with mature sagebrush.

Of the five chemically sprayed locations, the Muddy Creek and Badger Pass spray areas showed significant positive correlations for the two years since treatment. Six of the plowed and seeded locations lacked significant positive correlations in the first year after treatment. Five of these had significant positive correlations in later years.

It is concluded that unkilled sagebrush is the major cause of reinvasion. The generally low correlation values for all locations and years indicate that as long as there is some limited number of mature sagebrush plants present to provide seed, additional mature shrubs will not affect reinvasion. The lack of significant correlations for young plants over four years old indicates that factors affecting plant survival are of primary importance as the plants grow older.

Table 3. Regression coefficients of three study areas to determine whether sagebrush reinvaded brush control areas from adjacent sagebrush stands.

Reseeding area	Age Class	b value
Chinatown		
	Mature (treatment surviving)	–.0069**
	Reinvaded brush[1]	
	1961	–.0005*
	1962	–.0006*
	1963	–.0261**
	1964	–.0284**
	1965	–.0682**
Marchesseau		
	Mature (treatment surviving)	.0036
	Reinvaded brush[1]	
	1962	.0007
	1963	–.0016
	1964	–.0068*
	1965	–.0352
Taylor Creek		
	Mature (treatment surviving)	–.0018
	Reinvaded brush[1]	
	1963	.0003
	1964	–.0002
	1965	.0942**

* Indicates significance at the 5% level (one-tailed test).
** Indicates significance at the 1% level (one-tailed test).
[1] Years 1961 to 1965 represent plants present in 1965 by year of establishment.

Time of Treatment in Relation to Sagebrush Maturity.—Four of the plowed and seeded areas (Coyote Flat, Marchesseau, Cottonwood Creek, and Trail Creek) were believed plowed in late autumn after sagebrush seed maturation. The first year re-established sagebrush plants averaged 2.3, 0.3, 3.8, and 0.4 plants/m^2 respectively (Table 1). The exceptionally high early re-establishment rates likely resulted from a scattering of the new sagebrush seed crop throughout the freshly prepared seedbed. The reduced competition following plowing further served to insure high rates of early brush re-establishment. The practice of mechanically removing sagebrush in the autumn after seed maturation appears to assure severe reinfestation of the treated areas.

Wind-borne Seed.—Eight of the study locations were adjacent to sagebrush stands suitable for studying the influence of wind-borne seed on reinvasion. Table 3 lists three of the locations and their corresponding regression coefficients. Of the eight areas, only the Chinatown Reseeding had consistently significant and, generally speaking, slightly higher negative values than the other locations. Even these values for seedlings probably do not indicate seed movement into the treated area from the periphery. The mature plants (potential sources of seed) within the Chinatown Reseeding likewise had a negative value, indicating decreasing densities of unkilled brush from the edge inward.

Prevailing wind direction was not considered in evaluating wind-borne seed. Even though this is the case, it is felt that sagebrush adjacent to such large areas is of no practical importance as a seed source for reinvasion.

Influence of Non-sagebrush Vegetation on Reinvasion.—Basal intercept of live vegetation varied from 0.6 to 3.4%. In all of the correlations examined, only four of 95 were significant, and these were positive. With the exceptions of these four, no trend was found for either positive or negative correlations. Negative correlations would have indicated non-sagebrush vegetation was instrumental in preventing sagebrush re-establishment and positive correlations the reverse. The only conclusion which can be reached is that sagebrush re-establishment was not influenced by other vegetation.

Precipitation.—Studies in southwestern Montana have shown that sagebrush seed germinated in the spring as soon as temperatures became sufficiently warm (Mont. Agr. Exp. Sta., Progress Reports, 1961–64). In these studies, precipitation never limited germination. Temperature appeared to control germination, but the summer survival of the seedlings was thought to be limited by precipitation.

With this in mind, June to July, May to October, and annual precipitation patterns were studied to determine whether differences in precipitation accounted for differential reinvasion rates. Three study locations were selected for examining precipitation–reinvasion relationships. These were among the first treated and consequently best suited for regression analyses due to adequate sample size (determined by number of years since the treatment). In addition to the analyses of the three individual areas, all plowed locations and all 20 locations were considered collectively. The results of the regression analyses were non-significant in all cases.

Although these results indicate no relationship between precipitation and reinvasion rates, the possibility should not be discounted. It is possible that the proper precipitation data combination was not used. Perhaps an interaction of factors, including precipitation, is involved.

Effect of Soil and Topographic Characteristics.—The influence of each of these factors was tested only where major differences in a factor occurred within a treatment area.

Soil texture was significantly related to the re-establishment of big sagebrush in two of the seven areas where soil textures varied. In these two areas, the highest reinvasion rate was found on silty soil. Since reinvasion rates in relation to soil texture were not frequently found, it is concluded that soil texture was not well related to reinvasion rate.

Significant differences in sagebrush re-establishment among erosion classes were found within three of 17 locations, but the relationships were not the same among these locations. It is concluded that erosion severity is not related to sagebrush re-establishment.

In nine treatment areas re-established sagebrush varied significantly with respect to exposure. The northwest exposures generally were more favorable for re-establishment than south exposures.

Twelve areas were tested to determine if a relationship existed between percent slope and sagebrush re-establishment. Only two areas indicated that a relationship existed, with more sagebrush found on steeper slopes. Since 10 of these areas showed no relationship, percent slope cannot be considered an important factor.

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