The effects of some environmental influences on big sagebrush, Artemisia tridentata Nutt., reinvasion
by James Russell Johnson

A Thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Range Management
Montana State University

Abstract:
Twenty areas in southwestern Montana were chosen to examine several environmental factors thought to influence big sagebrush reinvasion. Fifteen of the areas were chemically sprayed and five were plowed and reseeded. The earliest year of treatment was 1957 and the latest was 1964, The factors examined for their influence on reinvasion were wind-borne sagebrush seed, the success of the brush control project, nonsagebrush vegetational competition, soil textural differences, yearly and seasonal precipitation patterns and totals, and date of plowing in relation to sagebrush seed maturity.

Field data were gathered along interrupted belt transects with paired plots at regular predetermined intervals. From three to 23 transects each 150 meters long were used in each of the 20 locations with 114 to 734 paired plots examined in every location. Data gathered at the paired plots were recorded on IBM Port-a-punch cards in the field and later transferred to standard 80 column cards for analyses. Arithmetic manipulation, regression, and correlation were used to evaluate the factors thought to influence reinvasion.

Eight locations were examined for wind-borne seed as a factor affecting sagebrush reinvasion. Adjacent non-treated sagebrush areas were found not to influence reinvasion.

The extent to which reinvaded sagebrush was found in association with treatment-surviving sagebrush shows reinvasion was inversely related to the initial success of the eradication. The correlations were low indicating a confounding of factors may have existed.

Non-sagebrush vegetation, as determined by basal intercept, was found not to influence reinvasion. Data to evaluate the influence of nonsagebrush vegetation on yearly reinvasion were collected in 1965. Had the collections been made yearly, the correlations may have been quite different.

The effects of surface soil texture, exposure, slope, and erosion on reinvasion and on basal cover by vegetation were analyzed. All factors, except exposure, showed very little influence on reinvasion. These results may be attributable in part to experimental procedure. The exposures to the north had greater reinvasion and basal cover by vegetation than did other exposures. This variation probably has more meaning in suggesting different exposures support different quantities and/or types of vegetation than an implication for planned sagebrush control.

Precipitation, both yearly and growing season, and sagebrush reinvasion rates were examined to determine if precipitation influenced reinvasion. No relationship was found for any of the three locations examined separately or for all the locations examined collectively. This shows factors other than precipitation precluded sagebrush survival. It is felt the unknown yearly death rate of reinvaded sagebrush, as well as probable changes in serai community-competition, and other factors may have masked possible relationships between precipitation and reinvasion.

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Approved:

R L Blackwell
Head, Major Department

Gene F Payne
Chairman, Examining Committee

Louis D Smith
Graduate Dean

MONTANA STATE UNIVERSITY
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ABSTRACT

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INTRODUCTION

In the upper Missouri River drainage area of Beaverhead County, Montana, considerable acreages of low forage value big sagebrush (Artemisia tridentata)[1/] ranges have been treated to control the brush. Generally little trouble is encountered in removing sagebrush from range lands believed capable of producing much greater quantities of grass. The two common methods of removal are by chemically spraying and plowing. In the former method the soil is not disturbed and existing grasses are encouraged to become dominant. In the latter method artificial seeding of desirable species is necessary.

The success or failure of sagebrush control can usually be related to (1) the initial kill of the sagebrush, and (2) identifiable rates of reinvasion following control. Environmental influences at the time of the control treatment and following the treatment may be important.

If the potential effectiveness of sagebrush control programs can be related to recognizable environmental influences, then the incidence of control program failures may be reduced. A study of some of the influences thought to be instrumental in sagebrush reinvasion consequently became the objective of this thesis.

The objective was reached by gathering and statistically analyzing field data on reinvasion, and attempting to relate patterns and intensities of reinvasion to yearly precipitation regimes; to surface soil texture, erosion class, slope, and exposure; to wind-borne seed; to the

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1/ Booth (1950, 1959) was the authority for scientific names of the plant species mentioned.

effectiveness of initial kill, including the time of plowing in relation to sagebrush seed maturity; and to competition with non-sagebrush vegetation.

Throughout the study it was assumed the microhabitat was uniform enough to allow expression and subsequent measurement of the environmental influences thought to affect sagebrush reinvasion. This underlying assumption probably was not correct because the environment was not controlled.

REVIEW OF LITERATURE

Introduction

Big sagebrush is a shrub of low forage value for livestock which is found in a wide range of elevation and geography. It is found as far east as Nebraska, as far north as British Columbia and Alberta, west to the Cascade Mountains of Washington, Oregon, and California, and south into Arizona and New Mexico (Pechanec et al. 1944b). Several crude estimates have been made regarding sagebrush occupancy. A Forest Service report (1945) estimated sagebrush was conspicuous on 96.5 million acres. A 1960 report by Beetle suggested the brush occupied 82.1 million acres or 228,000 square miles.

Beetle (1960) described big sagebrush as being an erect shrub normally from one to two meters tall but occasionally dwarfed or treelike. When treelike, sagebrush may be three meters tall with a trunk two decimeters in diameter. The numerous vegetative branches are erect, spreading above the base, 0.5 to 2.0 decimeters long, and perennial. The flowering stems are from three to four decimeters long, erect, rising above the vegetative branches, and supporting a rather dense open panicle which forms in mid-summer and matures by autumn. The heads may be produced in profusion. The achenes are small, ranging from 0.63 to 0.76 millimeters wide, from 1.2 to 1.7 millimeters long, and weighing from 0.00013 to 0.00028 grams.

Beetle (1960) stated the light grey-green appearance of the plant results from appressed pubescence. The leaves are persistent and when crushed give a pungent odor. The vegetative leaves are variable in size and shape, but may be described as linearcuneate, normally 3.0 centimeters long, and 0.5 centimeters broad, mostly with a three-toothed apex. Flowering shoots have smaller leaves which are generally entire, becoming sparse toward the panicle ends.

There appears to be a general consensus that sagebrush has become established in new areas and increased in density where already present. Lommasson (1946) in a 31 year study in Montana which terminated in 1945, concluded sagebrush was extending its range as a result of heavy grazing. He further noted there was an inverse relationship between the amount of sagebrush present and the amount of forage present on a range. Lommasson's conclusions were similar to those of many other workers including Frischknecht and Plummer (1955) who believed grazing had been responsible for changing luxuriant stands of herbaceous plants to big sagebrush stands in the Utah foothills. Cook (1963) reported sagebrush as a relatively unpalatable shrub to livestock which seriously competes with forage plants. He stated it had invaded millions of acres of deteriorated foothill range in the intermountain area with forage plant production reduced to a fraction of its potential. Blaisdell (1953) believed sagebrush was a natural component of range lands on the upper Snake River Plains of Idaho, but it often became too dense to support an understory of perennial grasses and forbs which he felt should be a part of the climax vegetation. Weaver and Albertson (1956) were of the opinion sagebrush was an invader which increased according to the reduction of native grasses due to grazing, the end result being greatly reduced grazing capacities.

Some observers believe proper grazing management will result in a reversal of the increased occupancy and density of sagebrush on those ranges capable of producing greater quantities of forage. Opposing this school of thinking are those who believe sagebrush, once established, is too competitive to lose dominance without a controlling factor being directly exerted on the sagebrush itself. Booth (1947) conducted a study on three sagebrush sites in the Madison Valley and the Gallatin Canyon in southcentral Montana. All of the sites had little evidence of grazing use. Almost no young (0-15 year) sagebrush plants existed in any of the sites. Booth concluded that sagebrush was not able to compete with native grasses in the areas investigated when grazing was light. He believed reduction of sagebrush would result from the combination of reduced reproduction and early death of mature sagebrush plants. Cooper (1953) in a study near Tensleep, Wyoming, supported Booth's findings with an eight year grazing trial. He found all three systems of deferment and rotation which he examined reduced sagebrush from a dominant species to a sub-dominant species. Annuals were replaced and perennial grasses became dominant. Observations by Millin (1950) in the Southwest led him also to believe sagebrush could be crowded out with proper management where western wheatgrass (Agropyron smithii) was abundant. Pechanec et al. (1944b) listed nine methods by which sagebrush may be reduced; competition was not one of those recognized. In his 31 year study in southwestern Montana, Lommasson (1946) found that sagebrush on the high grasslands of the Gravelly Mountain Range would maintain itself indefinitely under natural conditions and would increase in density. Millin (1950) felt that there were many areas in the West where competition would not crowd out sagebrush. These areas, he felt, were generally those where western wheatgrass was not abundant. Lommasson (1947) studied a burned area near Townsend, Montana, and resolved the area would remain dominated by sagebrush. Blaisdell (1949) made a study with seeded grasses on abandoned farm land in Idaho and found that if sagebrush plants were over two years of age, they were not greatly affected by subsequent grass establishment.

Bohmont (1954) felt forage production on a study area in the Wyoming mountains was often a third of what it could be if less sagebrush were present. Hyder and Sneva (1956) conducted a spray program on sagebrush near Burns, Oregon, and concluded forage production on sagebrush infested range lands could be doubled.

When artificial means of control have been exercised, the beneficial results may have been temporary as sagebrush persistently reinvaded those areas in which it had been subdued. Rapid reinvasion following sagebrush control was very common as reported by Pechanec et al. (1944b), Lommasson (1947), Frischknecht and Plummer (1955), Mueggler (1956), Weldon (1956), Robertson and Cords (1956), Bleak and Miller (1955), Goodwin (1956), Blaisdell (1949), and Cook (1963) as well as many others.

Sagebrush Reinvades - Why?

When reinvasion does occur, researchers generally attempt to relate the reinvasion to some causal factor or factors. If the factors which are responsible for reinvasion can be controlled, the reinvasion process can be slowed or eliminated.

Introduced or Residual Seed as Factors

The question of whether rapid reinvasion is a result of residual seed following treatment or of introduced seed from adjacent areas has often been a subject of study. Large numbers of sagebrush seedlings are frequently conspicuous in burned areas as well as in plowed areas subsequent to treatment. Mueggler (1956) studied the problem of introduced and residual seed quite thoroughly on five burn sites near Dubois, Idaho. The burns each occurred in different years from 1947 to 1954. In the fall of each year after a burn, transects were established on the recent burn and were permanently marked. Paired plots were located along the transects which originated at the edges of the burns. At least one transect extended for 10,000 feet across a burn site with plots at 50 or 100 foot intervals. One plot of each pair was protected from wind-borne seed and the other was left exposed. His results indicated wind-borne seed was restricted to within a few hundred feet of the edges of a treatment, and residual seed was by far the greater source of reinvasion.

Contrary to Mueggler's findings, Frischknecht and Plummer (1955) felt seed was transported from adjacent unburned sites to a small 45 acre burn site by wind and to some extent by animals. These investigators felt seed could not be residual as the burn occurred prior to seed set in the fall. They further contended residual seed could not have been deposited from previous years on the basis of earlier work with artificial seeding of sagebrush where no new plants became established after the first year. They also believed no sagebrush seed could have survived the very hot fire which consumed the litter as well as the brush. Pechanec et al. (1944a) agreed trailing livestock were capable of scattering sagebrush seed over cleared areas and might be the sole vectors of dissemination.

Goodwin (1956) described the morphology of the sagebrush seed and explained the pericarp has broken fibers at the base and slight scabrosity of the surfaces which allow adherence to passing objects when contact occurs. He also found the maximum distance of dissemination by wind to be about 33 meters, which he thought did not explain rapid reinvasion of large cleared areas. He concluded reinvasion may result from animal activity.

Success of Initial Control as a Factor

Closely related to the problem of edge effect on reinvasion of a control area is the problem of individual plants or groups of plants surviving within the control area. Lommasson (1946) in southwestern Montana described the problem of reinvasion from within the control area. In 1932 he cleared a small area by pulling all the sagebrush. Five growing seasons later two sagebrush plants 10 and 20 inches tall were present and believed to be reinvaded. The mode of reinvasion of these two was not discussed. Fourteen years after eradication there were 33 plants averaging two feet tall and 243 young plants less than four inches tall which averaged four years in age. Lommasson felt the location of the young plants indicated they came from the two older plants rather than from seed stored in the soil or from the periphery of the treatment area.

Frischknecht and Bleak (1957) conducted a study on range seeded in 1944 in northeastern Nevada. They found brush not eradicated was probably the seed source for many of the reinvaded plants which became established in several years subsequent to the treatment.

Bleak and Miller (1955) conducted a study in Nevada on two sites totaling 10,000 acres. They concluded sagebrush reinvasion resulted from seed produced by plants surviving eradication except when autumn brush eradication followed seed production in that year. Pechanec et al. (1944a) stated similar beliefs.

A study of sagebrush seedlings in relation to chemical control was conducted by Weldon (1956) in the Big Horn Mountains of Wyoming. Four growing seasons after the area had been sprayed, plots were studied to determine reestablishment of sagebrush. Weldon found rapid reinvasion could not be prevented unless initial sagebrush control exceeded 75 percent. This indicated reinvasion resulted from mature sagebrush not killed within the treatment area.

Date of Mechanical Eradication as a Factor

Sagebrush seed production and consequent potential reinvasion vary with the date of mechanical eradication. Bleak and Miller (1955) found spring eradication resulted in low kill of old plants due to flexibility of the plant and favorable moisture conditions for regrowth. The surviving sagebrush plants became prolific seed producers the following spring.

Pechanec et al. (1944a) as well as Bleak and Miller (1955) stated fall eradication after sagebrush seed set gave satisfactory control, but the action of the eradication process served to scatter the seed and prepare a good seed bed. Both studies reported a large crop of sagebrush seedlings the year after treatment.

Competition Between Sagebrush Seedlings and Other Vegetation as a Factor

Many studies have concluded seeded grass stands cannot become established unless the competitive effects of mature sagebrush are reduced (Robertson 1943, 1947; Pechanec et al. 1944a; Blaisdell 1949; and Cook 1958).

Blaisdell (1949) studied the relation between sagebrush seedlings and seeded grasses. He examined grasses drilled one and two years before sagebrush, simultaneously with sagebrush, and one, two, three, four, and five years after sagebrush establishment. He found that good stands of reseeded grasses established prior to sagebrush establishment either suppressed sagebrush seedlings or prevented sagebrush establishment for an indefinite period. He also found seeded grasses established concurrently with sagebrush would display an initial advantage, but eventually would become subordinate in the stand. Young sagebrush seedling stands allowed suppressed stands of seeded grass while older stands may have prevented establishment.

Frischknecht and Bleak (1957) studied an 825 acre planting of crested wheatgrass (Agropyron desertorum) in Ruby Valley, Nevada, 10 years after the planting. They found the younger age classes of sagebrush (less than three years old) were in plots which had basal cover of grass considerably less than the average basal cover of 10.2 percent. They suggested this recent reinvasion was related to localized heavy livestock use. Apparently the crested wheatgrass had largely excluded sagebrush established during the last period except where openings were large.

In 1947 Robertson reported on the effects of mature seed-producing sagebrush on initial invasion into native grasslands. He reported the areas near mature sagebrush which were normally void of grasses tended to allow sagebrush seedling establishment.

Beetle (1960) observed the survival of grass seedlings or sagebrush seedlings was directly related to the litter layer present. He stated the more the litter, the more the likelihood of seedling establishment of grasses, and the less the litter, the more the likelihood of sagebrush seedling establishment. He further noted that when sagebrush and grass seedling competition existed, the sagebrush root seemed more vigorous than the roots of most grasses, although the grass shoot seemed more vigorous and quicker to grow than the sagebrush shoot.

Pechanec et al. (1944a) reported an inadequate understory of perennial grasses could result in invasion by undesirable plants following sagebrush eradication, but competition by grasses prevented survival of sagebrush seedlings. He believed, however, successful seedings would not prevent such invasion the first year but might prevent invasion after the second or third year.

Soil as a Factor

On revegetated ranges previously dominated by big sagebrush, the interaction of soil factors and the control treatment is frequently considered. The soil relationships studied, however, are generally limited to moisture content, nutrient balance, erodability, or some other factor conducive to the brush eradication or the consequent desirable vegetation establishment (Pechanec et al., 1944a; Hyder and Sneva, 1956; Sonder and

Alley, 1961; Robertson, 1947; Cook, 1963; Hyder et al., 1962; and others). Little attention has been given to the possibility of some soil factor or factors being predictors in sagebrush seedling establishment. One notable exception is soil toxicity created by salt-affected soils. Hayward and Bernstein (1958) reported spotty stands and bare spots, which indicated poor germination or poor seedling emergence, could be a result of sensitivity of the germinating seed to salinity. In another study, Hull (1962) compared the topsoils from shadscale (*Atriplex confertifolia*), and big sagebrush on the establishment of several associated species. He found no difference in the ability of the topsoils to grow the seven species tested.

Precipitation as a Factor

Years favorable for natural sagebrush seedling establishment come at irregular intervals (Blaisdell 1949). The principal factor for seedling establishment seems to be available moisture (Bleak and Miller 1955).

On a sagebrush site which had been burned in 1941, Lommasson (1947) found rainfall the first year after the burn was 33 percent above average. The succeeding four years averaged 22 percent above normal. He stated the thrifty stand of sagebrush which became established the first year was a result of the ideal growing conditions created by the abnormally high precipitation.

In another study Lommasson (1946) correlated weather conditions with a sagebrush stand which became established on disturbed soil in 1885. He discovered the year of establishment coincided with a year of high precipitation. He further noticed a senile stand of sagebrush had very few seedlings until a seven year drought terminated, resulting in moisture conditions favorable for seedling establishment.

After observations, Beetle (1960) stated drought gave an advantage to sagebrush seedlings, and an absence of drought might allow the grass shoots to shade and kill the sagebrush shoots.

Wildlife and Sagebrush

Vegetation containing big sagebrush is known to be suitable habitat for antelope, deer, and grouse. Cole (1965) reported on a study in central Montana and found antelope were present in the sagebrush - grassland type of vegetation 49 percent of the total time. This amount of occurrence was the greatest for any of the vegetation types.

Along the Missouri River breaks of Montana, Mackie (1965) reported mule deer made the highest over-all use of the *Artemisia/Agropyron* vegetation type over a four year period.

Martin (1956) studied in southwestern Montana and found sage grouse preferred unsprayed sagebrush areas.

DESCRIPTION OF EXPERIMENTAL AREA

Location and History

The field research reported in this paper was conducted in Beaverhead County in southwestern Montana, mostly within 30 air miles of the Bannack townsite (Fig. 1). With the discovery of gold on Grasshopper Creek on July 28, 1862, a rush began which saw about 500 persons in this subsequently established town of Bannack by winter. By 1867 Argenta was a thriving mining town about 20 miles northeast of Bannack (Hamilton, 1957). Those rangelands around both towns and between the two were probably "free" range and used indiscriminately for a number of years. Extensive livestock use undoubtedly helped contribute to the present need for sagebrush control and revegetation in the area. Wildlife, including antelope (*Antilocapra americana*), deer (*Odocoileus* spp.), and sage grouse (*Centroercus urophasianus*), frequent much of the area. Buffalo (*Bison bison*) probably have not been in any of the adjoining valleys since 1882 (Lommasson, 1946).

The land on which the research was conducted is Federal land administered by the Bureau of Land Management. Most of the twenty locations studied (Table I) are leased to ranchers as grazing lands.

Fifteen plowed and seeded locations (Fig. 2) were examined as well as five sprayed locations (Fig. 3). In all, 28,681 acres were sampled (Table I). A detailed description of each study area, including location, size, shape, and grazing history is given in the Appendix.

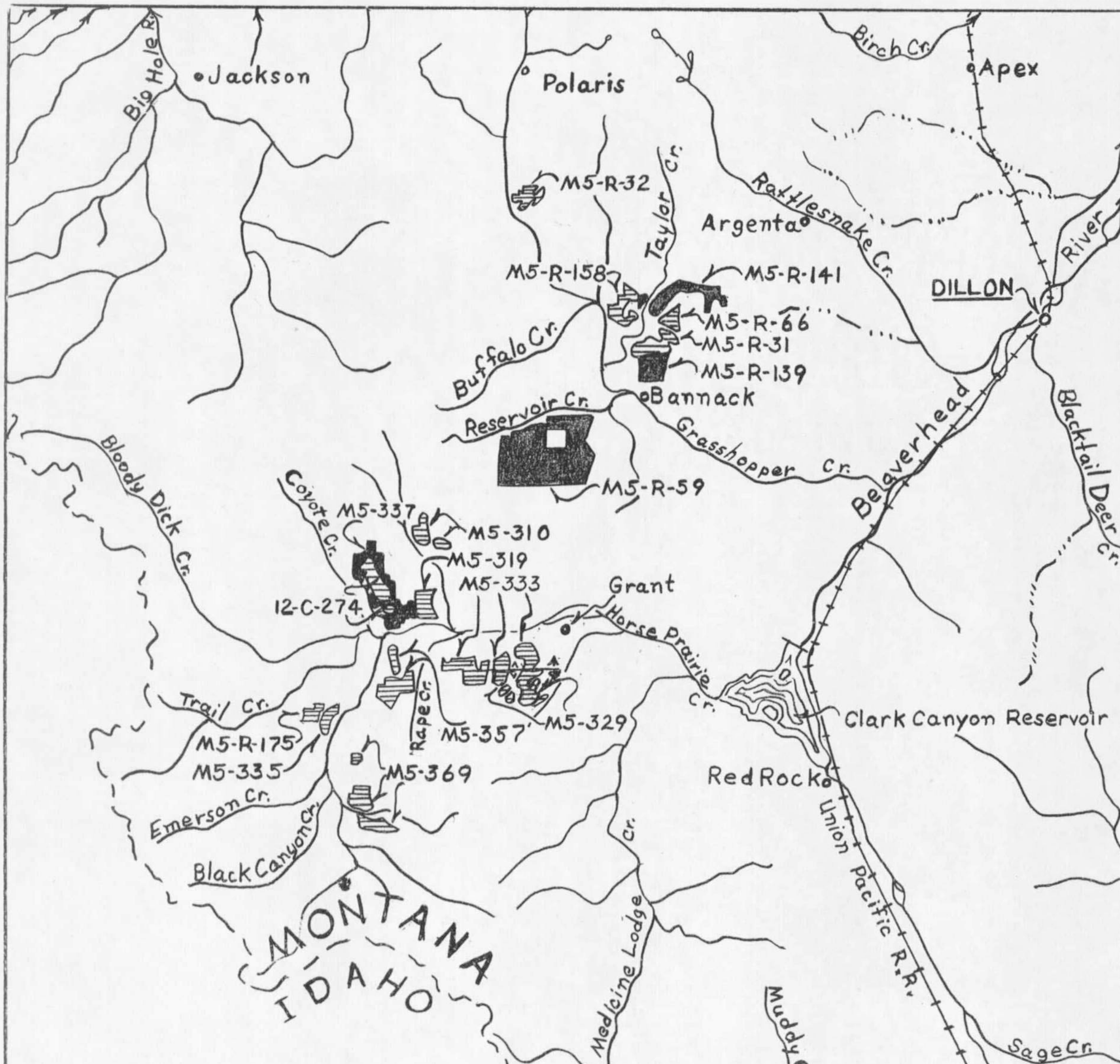

Figure 1. A map showing the locations of the 20 areas studied.