United States Department of Agriculture
NATURAL RESOURCES CONSERVATION SERVICE
Plant Materials Technical Note No. MT-68
July 2011

PLANT MATERIALS TECHNICAL NOTE

Big Sagebrush Establishment

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ABSTRACT

Big sagebrush and other sagebrush species establish naturally from seed, as well as from artificial seeding and planting. Seeds do not disperse long distances and natural establishment requires a local seed source. Where a natural seed source is not present, artificial seeding is most successful when the following conditions are met:

- A locally adapted seed source is used.
- Seeds have been recently collected, or if not, have been stored in cool, dry conditions for not more than three years.
- Seeding rate of 0.2 to 0.5 pounds pure live seed (PLS) per acre is used for a full stand. When seeded in a mix, the seeding rate should be a percentage of this rate.
- Seeds are sown in the late fall or early winter.
- Seeds are broadcast onto a firm but not compacted seedbed and pressed, rolled or dragged to improve seed-to-soil contact.
- Competition from annual and perennial non-native grasses is avoided.
- Grazing is deferred for two to five years.

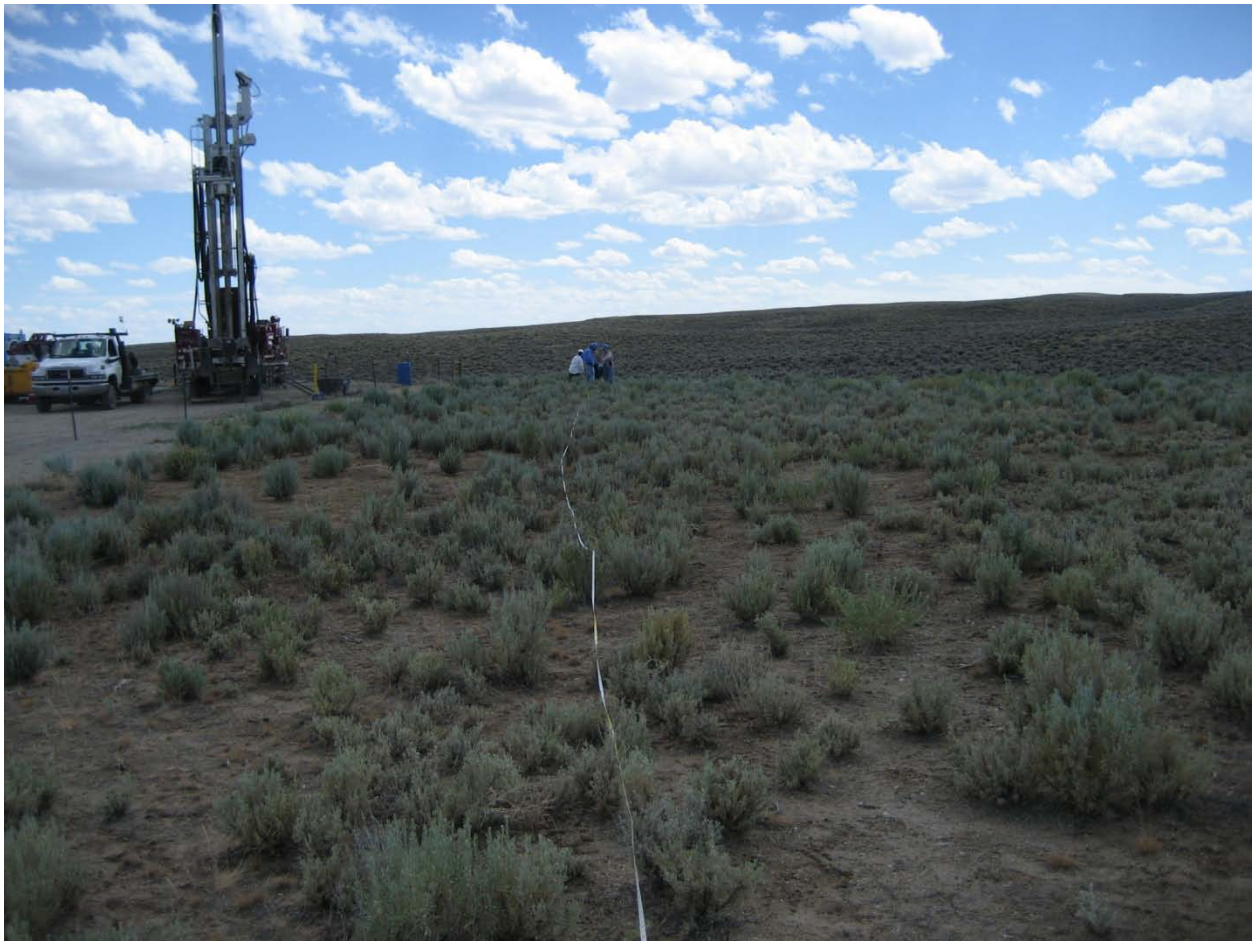

Figure 1. Four-year-old seeded Wyoming big sagebrush on a reclaimed gas well pad on the Pinedale anticline. The sagebrush was broadcast seeded in the Autumn of 2005 on a loose weed-free seedbed at 50 pure live seeds (PLS) per square foot (1.0 pound PLS per acre) and dragged to improve seed soil contact (Photo by Karen Clause, USDA, NRCS, Pinedale, Wyoming).

INTRODUCTION

Big sagebrush (*Artemisia tridentata* Nutt.) establishment has been studied over the last 50 years. The focus of early studies was how sagebrush populations regenerated after sagebrush removal treatments were applied to increase perennial forage for livestock grazing. These studies found sagebrush re-established naturally where there was a local population as a seed source. Where large areas of sagebrush were removed, particularly where fire was used or where natural fires burned large acreages, re-establishment was slow, as long as 50 years. It was learned that sagebrush populations do not produce a long-lived seed bank, seeds have high initial percentage viability, but do not survive more than one year on the soil, seed dispersal distances are short and generally less than 15 yards but may be as far as 100 yards from the parent plant, and most sagebrush species do not sprout from stumps or roots.

In the 1970s, sagebrush species began to be recognized for their wildlife food and cover values. Big sagebrush browse was also recognized as palatable to some classes of livestock. Much of the more recent work has studied re-establishing sagebrush populations after wildfire, mining and gas exploration disturbances (see Figure 1). Recent studies have focused on artificial seeding, or planting bare root or containerized stock. These studies found seeding technique, seed source, and seed storage affected sagebrush population establishment when artificially seeded. It was learned establishment after aerial seeding was unreliable. A BLM study found no difference in Wyoming big sagebrush establishment between aerially seeded plots and naturally regenerating plots following wildfires on the Snake River Plain in southern Idaho. In that study,

there was no sagebrush establishment of aerially seeded sagebrush in 23 of 35 sites sampled. However, aerial seeding on snow has been successful in many areas.

It was also determined that competition from non-native grasses greatly increased the risk of seeding failure. In fact, there was no big sagebrush establishment where there was competition from annual or perennial non-native grasses. Where there was not competition from non-native grasses, establishment improved when a local seed source of an adapted big sagebrush sub-species was used, seeds were broadcast on the soil surface followed by a soil incorporation treatment, and grazing was deferred until plants reached reproductive maturity (a minimum of two years).

Sagebrush also established after transplanting bare root or containerized stock; however it was more costly than direct seeding. First year survival rates of transplanted stock has been 80% or greater. Surviving plants can be reproductive in three to five years, providing a seed source for population establishment and justifying the cost of transplanting particularly where artificial seeding is impractical.

The following summarizes the biology and ecology of sagebrush important to sagebrush establishment and forms the basis of seeding recommendations. Most of the information available is for big sagebrush.

REPRODUCTIVE BIOLOGY

Most sagebrush species reproduce solely by seed with only a few species able to re-sprout following fire or other disturbance. Big sagebrush, like most North American sagebrush species, flowers from late summer into autumn (see Figure 2 for a drawing of a sagebrush flower and inflorescence). From mid-autumn to early winter, fertile florets ripen into one-seeded fruits called achenes (see Figure 3).

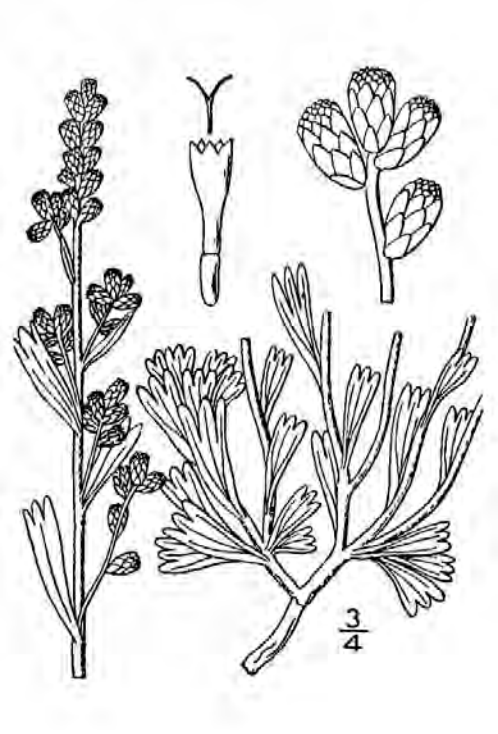

Figure 2. A drawing of big sagebrush leaves, inflorescence, flower heads and floret. (Britton, N.L., and A. Brown. 1913. *An illustrated flora of the northern United States, Canada and the British Possessions. 3 vols.* Charles Scribner's Sons, New York. Vol. 3: 530. Courtesy of Kentucky Native Plant Society.)

The walls of the achenes are papery and membranous with mucilaginous nerves on the outside. The endosperm of the seed within the achene is membranous with little carbohydrate reserves, and the well-developed embryo fills the interior of the seed. Achenes are small, generally less than 0.06 inches (1.5 millimeters) in diameter, and light weight (100 achenes weigh about 25 milligrams or less).

A plant can produce 500,000 achenes, but the number is highly variable depending on the climatic conditions, competition with other plants for resources, herbivory, and seed predation among other factors. Most achenes shed within a few weeks of maturity, and generally fall within a few feet of the parent plant. Achenes have no morphological adaptations to facilitate dispersal, but because they are light weight, they can travel on wind currents over hard surfaces or snow crusts and have been reported (although it is uncommon) to disperse nearly 100 yards from the parent plant. Animals and water may also disperse achenes long distances.

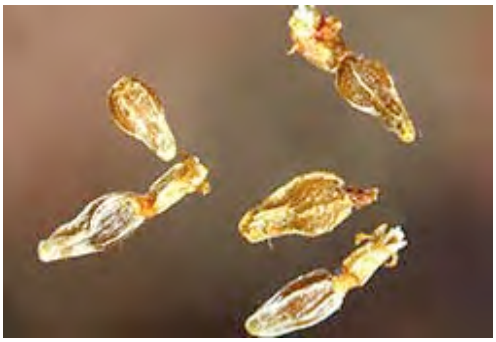

Figure 3. De-bearded sagebrush seeds about ten times their actual size. Photo by Scott Baurer, USDA ARS.

SPECIES AND SUBSPECIES ADAPTATION

Each sub-species of big sagebrush (basin, mountain, and Wyoming) have different germination requirements, establishment traits, growth rates, and needs for moisture and temperature and do not establish well outside their specific habitat. In addition, populations within a sub-species have local or regional adaptations including cues for germination. Germination outside of the area of adaptation increases the risk of seedling death.

SEED QUALITY

Sagebrush seed is collected by beating or stripping inflorescences into containers resulting in low purity because of a large percentage of flower parts, leaves, and other plant litter. The timing of collection greatly influences seed quality; collecting before seed ripening or after dispersal results in a high proportion of unfilled seeds or aborted fruits. Seed purity at collection may be only 10%. Cleaning using de-bearders, screens and fans results in purities of 50% or greater without loss of viability. A 21-day germination test at 59° or 68° F (15° or 20° C) with light is recommended for testing viability. Some collections will not germinate during the 21-day test period because of dormancy, and tetrazolium staining is an alternative to germination testing for viability. The viability test is a better indicator of seed quality than the purity of a seed lot because half-filled and aborted seeds have little effect on percent purity but will reduce percent viability considerably. High quality seed with half-filled or aborted seed excluded generally has viability at 90% or greater. Seeds lose quality relatively rapidly under storage. However, seeds stored in low humidity (6 to 8% optimum) and cool temperatures (less than 50° F or 10° C) will maintain quality for two or three years.

SEED GERMINATION

The germination of big sagebrush seed is variable depending on subspecies and local ecotype, and is related to climatic variation. At dispersal, seeds have a low level of dormancy but are slow to germinate, requiring exposure to light or moist chilling (stratification). Most seeds are ready to germinate after winter, but studies show that light requirements or stratification that enables germination is related to habitat conditions of the collection site. Data suggests these habitat-correlated germination patterns are exhibited by big, silver, black, and low sagebrushes. While most seed germinate during the first year, seed buried in the soil or covered with litter or mulch has been reported to live up to four years. However, generally there is no long-lived seed bank. Seeds germinate from late winter to early spring, or where snow accumulates, soon after snowmelt. Montane populations can germinate under snow cover. The mucilaginous nerves on the achene wall along with hairs align the achene and facilitate seed-to-soil contact enabling soil penetration by the embryonic root (radical).

SEEDING RATE

The Woody Plant Seed Manual (2008) gives a range of seeding rates for big sagebrush from five to nine PLS per square foot as adequate for population establishment. While seed size is variable among sub-species and eco-types (approximately 1.7-2.4 million seeds per pound), this equates to a range of 0.1 to 0.2 pounds PLS per acre. Booth and Bai (2000) recommend a seeding rate of 1,000 seeds/m^2 (about 2 PLS pounds per acre) based on a survey of reclaimed mine sites, and believe high seeding rates are consistent with sagebrush ecology.

Regression analysis of data from a BLM study in southern Idaho where Wyoming big sagebrush was aerial seeded after wildfire found no relationship ($p=0.71$, $R^2=0.0$) between seeding rates ranging from less than 0.1 to about 0.6 pounds PLS per acre and the density of shrubs that established on seeded sites. However, observations from a field planting on a reclaimed gas well pad near Pinedale Wyoming suggest seeding rate and planting method influence sagebrush establishment. In one native seed mix, Wyoming big sagebrush established within five years of seeding at 436 shrubs per acre when drill seeded at 0.01 PLS per acre (2% establishment), and 3,049 shrubs per acre when ground broadcast at 0.02 PLS per acre (6% establishment). Establishment of a second native mix was 6,534 and 16,988 shrubs per acre when drilled at 0.5 PLS per acre (1% establishment) and ground broadcast at 1.0 PLS per acre (1% establishment), respectively. These observations suggest establishment increases as seed rate increases regardless of whether seeds are drilled or broadcast. The percentages of establishment suggest there may be a point of diminishing returns in seedings where cost is a factor.

The mine land reclamation industry recognizes the benefits of increased seeding rates in meeting requirements for bond release. Observing high natural seeding rates, they have found the cost of relative over-seeding is justified by increased population establishment, and compensates for heavy browsing by wildlife. On the other hand, high seeding rates result in near monocultures of sagebrush where no understory plant diversity leaves the site susceptible to invasion by annual grasses and thus exposure to high incidence of wildfire.

ESTABLISHMENT

Big sagebrush, and most sagebrush species, establish naturally by seed provided there is a local seed source. Natural re-establishment of populations after large-scale fire or other disturbance is slow because the local seed source has been destroyed. Artificial seeding can reliably establish populations provided natural processes are followed. Locally adapted seed sources will be stimulated by local climatic conditions to germinate at the optimum time to improve seedling survival. Seeds naturally disperse in late fall or early winter, and artificial seeding in late fall or on snow has been successful. Spring seeding is not recommended. Seeds

naturally disperse onto the soil surface where dormancy is regulated by light, moisture, and temperature for optimum timing of germination. Broadcast seeding is recommended, and some type of operation to improve seed-to-soil contact such as pressing, dragging or rolling will improve establishment. Brillion or modified Brillion seeders are used to seed reclaimed mine land, but do not perform well where a clean seed bed has not been prepared. Drilling or broadcasting seed too deeply into the soil prevents the small seed from successful emergence. Seed should be placed near the soil surface not to exceed a depth of 1/8-inch. If drilling seed, it is advisable to partition seed boxes and drills to plant the slower developing sagebrush in separate rows from more rapidly developing grasses and forbs when seeding a species mixture. A firm, but not compacted, seedbed will provide seed-to-soil contact important for germination and seedling survival. Competition from non-native grasses reduces seeding success and seeding where exotic annual grasses dominate almost always fails. Seeding sagebrush in a mixture of native forbs and bunchgrasses is recommended where wildlife habitat is the conservation objective.

On highly disturbed sites such as mine lands, cultural methods will influence sagebrush establishment. Establishment is greater on fresh as opposed to stockpiled soil most likely because of sagebrush's mycorrhizal association that aids in water and nutrient uptake from the soil. Stubble or surface applied mulch improves establishment and herbaceous competition reduces establishment. Big sagebrush density, soil resource stability, and forage production may be adequately provided when native grasses are seeded at a rate of 3.6 to 12.5 pounds per acre.

Figure 4. Big sagebrush seedlings.

Propagation of plants from seeds is relatively easy. Seeds of northern plains sources grown at the Bridger PMC did not require dormancy breaking treatments prior to germination. Other references report up to five months of cold; moist chilling is needed for optimum germination. Agitation of seeds in a rubber-lined rock tumbler with tap water is also said to enhance germination in one reference. Duration in the tumbler is subjective, depending on the appearance and condition of the seeds. The water in the tumbler is changed daily. In most cases, however, seeds collected the previous fall can be directly sown on the surface of a peat-based propagation media with no pre-treatment. Immediately hydrate seeds and keep moist until germination occurs. At the Bridger PMC, propagation begins in the early spring in 7-cubic-inch containers placed in a greenhouse maintained at 75^0 to 80^0F days, and 60^0 to 65^0F nights, with 16-hour photo periods. Germination typically begins 10 to 14 days after sowing and is mostly complete within 30 days. Weekly fertilization with 100 to 150 ppm nitrogen begins two to three weeks after germination has finished. Water soluble products are used at Bridger. Rinse

plant foliage lightly after liquid fertilization to prevent foliar burning. Water seedlings in the early morning hours in order to allow adequate time for the foliage to dry prior to evening. Seedlings are moved from the greenhouse to a shade covered hoop house in mid- to late-June, then relocated to partially shaded outdoor benches in August until winter when they are stored in a plastic covered hoop house. Depending on growing conditions, transplanting of seedlings into 40-cubic-inch containers with peat based media amended with slow release fertilizer may be required by mid-summer. Plants held over for a second growing season may require pruning and transplanting into one or two gallon containers. Plants overwintering in the container at least one winter prior to out-planting typically perform better than seedlings out planted their first growing season.

Planting of containerized and bare root stock has been successful. Plants established from containers may produce less seed, smaller top growth, and shallower root systems than plants established from seed. Moisture conditions are favorable and planting most successful in the spring. Container size increases the size of the planting stock but it is not known if this confers an establishment advantage.

POST-SEEDING MANAGEMENT

Livestock and wildlife use can reduce seeding success. Protection from grazing and trampling during establishment will reduce the risk of seeding failure. Livestock should be excluded from seeded sites until shrubs become reproductive, a minimum of two years. Monitoring establishment identifies when shrubs are reproductive and can be used to determine when grazing is permitted. Livestock grazing at a light to moderate stocking rate and low stock densities in late spring to early summer where forage utilization is less than 60%, or heavy or season-long grazing, may increase sagebrush density and cover. Prescribed grazing can be used to maintain plant community health and diversity after shrubs have established and are reproductive. Planting or maintaining native understory species favors big sagebrush recruitment for sustainable populations.

RECOMMENDATIONS

- Specify objectives for sagebrush establishments. Some wildlife habitat requires a combination of native grasses, forbs, and shrubs.
- Artificially seed where there is not a sagebrush population within 100 yards to serve as a seed source.
- Use seed from a local sagebrush population or from a population adapted to site climate conditions.
- Use seed collected recently or stored for no more than three years in cool, dry conditions. A recent germination test is required for older seed.
- Seed at a rate of five to nine PLS per square foot (0.1 to 0.2 pounds PLS per acre).
- Include only native grasses and forbs in the seed mix.
- Prepare a firm, weed- and non-native grass-free seedbed.
- Broadcast seeds in the late fall or early winter and press, drag, or roll after seeding.
- Defer livestock grazing until after established shrubs are reproductive, generally two to five years, and then prescribe grazing to maintain a diverse habitat.

- Plant containerized or bare root stock in early spring where seeding is not practical or does not meet objectives.

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