Black stem rust reduces big sagebrush seed production

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Abstract

We conducted an experiment to determine the effects of a rust disease on big sagebrush (*Artemisia tridentata* Nutt.) seed production. We ranked 760 plants as to disease intensity in an established 'Hobble Creek' mountain big sagebrush (*Artemisia tridentata* ssp. *vaseyana* Rydb. Beetle) seed-increase garden. These rankings were divided into 4 classes: I. very light intensity; II. light intensity; III. medium intensity; and IV. heavy intensity. Three years after planting all plants in the test showed signs of infection. The heavier the infection the fewer seeds produced. Cost of the rust disease was estimated at about \$3,862 ha⁻¹.

Key Words: *Artemisia tridentata* ssp. *vaseyana* Rydb. Beetle, 'Hobble Creek', *Puccinia tanacetii* DC

Big sagebrush (*Artemisia tridentata* Nutt.), provides food, nesting sites, and cover to a number of wildlife species. Animals that have been observed feeding directly on big sagebrush include: sage grouse (*Centrocercus urophasianus*), pygmy rabbit (*Brachylagus idahoensis*), pronghorn antelope (*Antilocapra americana*), mule deer (*Odocoileus hemionus hemionus*), Rocky Mountain elk (*Cervus elaphus nelsoni*), Rocky Mountain cottontail (*Sylvilagus nuttallii*), black-tailed jack rabbit (*Lepus californicus*), dark-eyed junco (*Junco hyemalis*), hornedlark (*Eremophila alpestris*), white crowned sparrow (*Zonotrichia leucophrys*), Uinta ground squirrel (*Citellus armatus*), domestic sheep (*Ovis aries*) and a host of arthropod species (Green and Flinders 1980, Kufeld et al. 1973, Martin et al. 1951, Patterson 1952, Smith and Beale 1980, Welch 1993, 1994). Some of these animals such as sage grouse, are obligatory feeders on big sagebrush; most, such as mule deer, are facultative feeders. Plant parts eaten by these animals include leaves, stems, flower stalks, seeds, and pollen.

Big sagebrush plants provide a preferred platform for nest building for sage thrasher (*Oreoscoptes montanus*), sage sparrow (*Amphispiza belli*), and Brewer's sparrow (*Spizella breweri*) Braun et al. 1976, Medin 1990, 1992).

As the range management community gradually accepts the idea that big sagebrush is a desirable plant, the demand for big sagebrush seed for use in revegetation projects has increased

from a few to several thousands kilograms per year. To help meet this demand, some seed growers have established seed-increase gardens of big sagebrush cultivars and selections. In a seed garden of 'Hobble Creek' (Welch et al. 1986) mountain big sagebrush (*Artemisia tridentata* ssp. *vaseyana* Rydb. Beetle), we observed the build-up of a rust disease. The 2 primary objectives of this study were: document the build-up of the disease, and measure the impact on seed production. Two secondary objectives were, describe the nature of damage and compare the infection intensity of the garden to a nearby native stand of mountain big sagebrush and to the 'Hobble Creek' breeder block at the site of origin.

The Rust Fungus

The rust fungus causing the disease is *Puccinia tanacetii* DC (Arthur 1962). The disease is referred to as "black stem rust" because of the conspicuous and characteristic "blackening" of inflorescent stems resulting from dense sporulation of the black telial sori (fruiting structures). Arthur (1962) listed *P. tanacetii* as occurring on 35 species of *Artemisia* in North America. In the U.S. *P. tanacetii* occurs on *Artemisia* in all but 3 states west of the Mississippi River, Wisconsin, the 3 most southwestern provinces of Canada, Mexico, Central America, Europe, and Japan. On big sagebrush (*A. tridentata*), *P. tanacetii* has been collected in all 11 conterminous western states except Arizona. *P. tanacetii* is an obligate parasite and all spore stages (pycnial, aecial, uredinal, telial) occur on one host.

Materials and Methods

In March of 1990, we established a 'Hobble Creek' mountain big sagebrush seed-increase garden about 3 km south of Bluffdale, Ut., at The Point of the Mountain. About 2,070 containerized plants were transplanted onto the site. The containerized stock was produced as outlined by Nelson (1984). Site preparation consisted of plowing and disking to remove all existing vegetation.

Elevation at this site is about 1,372 m. The average annual precipitation is about 305 mm. Welch et al. (1986) demonstrated that 356 mm of annual precipitation is needed for this cultivar to sur-

vive. Supplementary irrigation (50 to 100 mm) in the form of flooding or sprinkling was applied during the first 2 years. The soil on the site is Bingham gravelly loam. The soil is deep, well-drained and is derived from igneous and sedimentary rocks. About 100 mm of available water is held to a depth of 1.5 m. Soil pH ranges from 6.6 to 7.5. Rooting depth in this soil is less than 50 to 76 cm (Woodward et al. 1974). The average frost-free period is about 160 days. Permeability ranges from 102 to 160 mm per hour (Woodward et al. 1974).

Once a year in the fall from 1990, we checked each plant for signs of the rust disease. The disease was identified by the presence of small black fruiting bodies or telial sori of the pathogen (Fig. 1). With heavy infections, the sori appeared as black streaks and spots on stems and leaves (Fig. 1).

By the third growing year (1993), the disease had spread throughout the garden. The intensity of rust infection varied from plant to plant. We devised an ocular method of partitioning infection intensity into 4 classes (Fig. 2). Class I represented a very light infection level that required some hand searching through vegetative and inflorescent shoots to locate the widely scattered telial sori. Class II represented a light infection level and required

Table 1. Analysis of Variance and test of significant difference among the seed yield of 4 classes of rust infection intensity. Each class was represented by 10 'Hobble Creek' mountain big sagebrush plants growing in a seed-increase garden. Data expressed as the mean of 10 plants per class. Seed yields given in grams of pure live seed (pls).

Source	Degrees of freedom	Analysis of variance	
		Mean square	F*
Among classes	3	3570.613	31.79
Within classes	36	112.297	
Total	39		

Test of significant difference				
Infection class	I	II	III	IV
Grams pls	43.9 ^{a1}	39.3 ^a	16.4 ^b	4.0 ^c

*a = 0.05

¹Means with the same superscripts are not significantly different at the 5% level, Newman-Keul's multiple range test.

no hand searching. Class III represented a medium infection level and Class IV a heavy level. Each class represented about a doubling of the infection.

We rated all plants on the first 20 rows of the garden, amounting to 760 plants. After rating, all plants in a class were pooled and 10 plants per class were selected at random. These plants were used to measure the effect of the rust disease on seed production. The test plants were harvested on 15 November 1993.

Inflorescences were removed by use of a handclipper and placed in plastic bags. The inflorescences were then dried by placing the plastic bags in a heated (20° C) greenhouse. The bags were left open and the inflorescences hand stirred each day. The main stems of the inflorescences were hand stripped of seeds, achenes, floral bracts, fine stems, and leaves after drying. A 14 × 14 mesh screen was used to separate fine stems and intact leaves from seeds, achenes, floral bracts, and broken fine stems and leaves. The resulting material was rubbed on a finely seated board to further free achenes from florets.

Final seed cleaning was done with a small-lot air-lift seed cleaner. The cleaned-seed lots from each of the 40 plants were weighed to the nearest 0.1 gram, and used to determine seed purity and viability. Seed purity was determined from a 0.3-gram sample by separating filled seeds or achenes from broken or aborted fruits and chaff. These 2 allotments were weighed to 0.0001 of a gram and purity calculated. Seed viability for the 40 seed lots was determined by using the tetrazolium staining test (Grabe 1972) as outlined by Meyer et al. (1987), except that we immersed seeds in the buffered tetrazolium solution for 24 hours instead of 6. Seed lot weights, purity, and seed viability were used to calculate the amount of pure live seed produced by each plant. Data collected were analyzed using one way analysis of variance ($P \leq 0.05$). Treatments were the 4 infection intensity classes. Replications were the 10 randomly chosen plants for each class. Newman-Keul's multiple range test was used to detect differences among treatment means ($P \leq 0.05$).

We rated the rust infection intensity of 100 plants in a small native stand of mountain big sagebrush located about 100 m southwest from the seed garden. The same data were collected from 50 plants at the 'Hobble Creek' breeder block (50 by 50 m), or site of origin located near the mouth of Hobble Creek Canyon about 48 km southeast of the seed garden. This data set allowed us to compare the infection intensity of the breeder block (50 plants) to a native stand growing near the garden (100 plants),

Fig. 1. Nature of the black stem rust disease on mountain big sagebrush (*Artemisia tridentata* ssp. *vaseyana*). The black circular structures are the telial sori of the rust fungus *Puccinia tanacetii* (magnification 10x).

Fig. 2. Illustration of the 4 rust fungus infection intensity Classes I, II, III, IV. Inflorescent shoots (left to right) with corresponding enlargement below showing intensity level of telial sori on leaves, stems, and florets. (1/3 actual size of inflorescent shoots, 2x magnification of telial sori).

and the seed-increase garden (760 plants). Data were statistically analyzed by means of a 3×4 contingency table (3 sites, 4 classes).

Results and Discussion

No rust infected plants were found in the garden in 1990, signs of disease were found on 15 plants in 1991, 247 plants in 1992, and all 1,986 live plants in 1993. The 1992 increase from 15 to 247 infected plants represents a 16.5 fold increase vs. a 8.0 fold increase between 1992 and 1993.

Effect of the black stem rust disease on seed production is given in Table 1. Because all plants of the seed increase garden were infected, we do not know what the seed yield would be for uninfected plants. However, we do not believe that the seed yield of uninfected plants would be significantly different than the yield of the lightly infected plants of Class I.

The economic effect of black stem rust is dramatic. Based on

our seed yield data, a price of \$88.19 per kilogram of pure live seed, and 2,250 plants per hectare (ha^{-1}), we estimated that the disease reduced the gross income by \$3,862 ha^{-1} . Using the average seed yield of Classes I and II as an estimate for uninfected plants, we calculated a potential gross seed yield value of \$8,252 ha^{-1} . The 1993 seed yield, affected by black stem rust, was calculated by using the percentage of plants in each class and yield per plant (Class I 4.1%; 43.9 gm; Class II 27.1%, 39.3 gm; Class III 55.9%, 16.4 gm; Class IV 12.9%, 4.0 gm) for a value of about 49.82 kg ha^{-1} or a gross income of about \$4,390 ha^{-1} .

With heavy infection (classes III and IV), during mid to late summer, we observed that both ephemeral and persistent leaves began to defoliate. Defoliation became severe especially on vegetative shoots, and continued through fall and winter. The indeterminate growth of inflorescence shoots, enhanced by favorable moisture, continued even into flowering. With heavily infected plants, there was a noticeable stunting of inflorescent shoots and an inhibition of floret development. Only a few of the late-forming florets on the tips of shoots eventually flowered. The contrast

Table 2. Chi-square comparison among 3 sites for intensity of rust infections. Classes listed represent increasing severity of rust infection from class I to IV. Data based on a ranking of 50 plants for the breeder block, 100 plants for the native stand, and 760 plants for the garden.

Infection class	Breeder block	Site	
		Native stand	Garden
Class I	20 (40%) ^{a1}	1 (1%) ^a	31 (4%)
Class II	19 (38%)	44 (44%) ^a	206 (27.1 %)
Class III	10 (20%) ^a	54 (54%)	425 (55.9%)
Class IV	1 (2%) ^a	1 (1%) ^a	98 (12.9%)
Total plants per site	50	100	760

^{1a} = Cells with a significant difference between observed and expected values at the 5% level.

in floret development on inflorescent shoots, with the 4 classes of infection intensity, is illustrated in Figure 2. Decrease photosynthetic capacity of plants by defoliation, stunting and inhibition of floret development is likely the main cause of reduced seed productivity. Future studies are needed to quantify these observations.

Comparison of the black stem rust infection intensity at the 3 sites is given in Table 2. Because the genetic composition of the plants in the breeder block and seed increase garden was similar, and the rust fungus was widespread, the higher infection level at the garden can be reasonably attributed to either environmental site differences or differences in the genetics of the rust. Future studies are needed to determine the factors involved in the build-up of the disease.

There appear to be at least 2 avenues for development of control; genetic resistance and the use of fungicides. Most of the plants rated as Class I expressed a hypersensitive type resistance reaction. It may be possible to develop a variety of 'Hobble Creek' mountain big sagebrush with some genetic resistance. Preliminary evaluation of several fungicides shows promise in controlling black stem rust.

Literature Cited

- Arthur, J.C. 1962. Manual of the rusts in United States and Canada. Hafner Pub. Co., N.Y.
- Braun, C.E., M.F. Baker, R.L. Eng, J.S. Gashwiler, and M. Schroeder. 1976. Conservation committee report on the associated avifauna. Wilson Bull. 88:165-171.
- Grabe, D.F. 1972. Tetrazolium testing handbook for agricultural seeds. Contr. 29 to the Handbook on Seed Testing, Assoc. Official Seed Analysts.
- Green, J.S. and J.T. Flinders. 1980. Habitat and dietary relationship of the pygmy rabbit. J. Range Manage. 33:136-142.
- Kufeld, R.C., O.C. Wallmo, and C. Feddema. 1973. Food of the Rocky Mountain mule deer. USDA For. Serv. Res. Pap. RM-111, Rocky Mt. For. and Range Exp. Sta., Fort Collins, Colo.
- Martin, A.C., H.S. Zim, and A.L. Nelson. 1951. American wildlife & plants: A guide to wildlife food habits: the use of trees, shrubs, weeds and herbs by birds and mammals of the United States. Dover Publ. Inc., N.Y.
- Medin, D.E. 1990. Birds of an upper sagebrush-grass zone habitat in East-Central Nevada. USDA For. Serv. Res. Pap. INT-433, Intermountain Res. Stat., Ogden, Ut.
- Medin, D.E. 1992. Birds of a great basin sagebrush habitat in East-Central Nevada. USDA For. Serv. Res. Pap. INT-452, Intermountain Res. Sta., Ogden, Ut.
- Meyer, S.E., S. Kitchen, G.R. Wilson, and R. Stevens. 1987. Supporting evidence for the proposed rule *Artemisia tridentata* big sagebrush. Unpublished report submitted to the Assoc. of Official Seed Analysts on file.
- Patterson, R.L. 1952. The sage grouse in Wyoming. Sage Books, Inc. Denver, Colo.
- Smith, A.D., and D.M. Beale. 1980. Pronghorn antelope in Utah: Some research and observations. Pub. 80-13. Utah Division of Wildlife Resources, Salt Lake City, Ut. p. 88.
- Welch, B.L. 1993. Grass is not always king. p. 1775-1778 In: M. Baker (ed.), Proc. of the XVII Int. Grassl. Congress. Palmerston North, New Zealand.
- Welch, B.L. 1994. Rangeland shrubs. p. 3:575-586. In: C.J. Arntzen (ed.), Encyclopedia of agricultural science. Academic Press, Inc. San Diego, Calif.
- Welch, B.L., E.D. McArthur, D.L. Nelson, J.C. Pederson, and J.N. Davis. 1986. 'Hobble Creek'—A superior selection of low-elevation mountain big sagebrush. USDA For. Serv. Res. Pap. INT-370, Intermountain Res. Sta., Ogden, Ut.
- Woodward, L., J.L. Harvey, K.M. Donaldson, I. Shiozaki, G.W. Leishman, and J.H. Broderick. 1974. Soil survey of Salt Lake area, Utah. USDA Soil Conserv. Serv., Salt Lake City, Ut.