Wyoming Big Sagebrush: Coping With Drought

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SUMMARY: The effects of drought on Wyoming big sage brush were evaluated. Plant water status, water use, growth, and nitrogen content were measured during two growing seasons. Response was measured at two locations, both representing a Wyoming big sagebrush/Thurbers needlegrass habitat type. One site had been seeded to crested wheatgrass. The second location contained an understory of native species. Precipitation was 106 and 67 percent of the long term mean during the 1989 and 1990 crop years, respectively. Limited soil water availability in the drought year decreased plant water status, water use, and nitrogen content in big sagebrush. The ability of big sagebrush to cope with drought was expressed through morphological plasticity. Under drought stress, Wyoming big sagebrush partitioned more biomass to vegetative versus reproductive shoots, leaves versus stems, and perennial versus ephemeral leaves. Limited soil water also greatly reduced secondary ephemeral leaf and lateral shoot development.

The drought tolerant shrub, big sagebrush (*Artemisia tridentata* Nutt.) is the dominant shrub characterizing the Intermountain Sagebrush Steppe. In the past 120 years, sagebrush abundance has increased two to four-fold at the expense of the herbaceous understory. Uncontrolled livestock grazing of the herbaceous understory has been described as one of the primary factors contributing to the increase in sagebrush density and cover throughout the sagebrush steppe. Drought has also been attributed to increased density of sagebrush.

Drought is a common phenomenon throughout the Intermountain Sagebrush Steppe, with precipitation falling below 70 percent of the mean one year in five. Drought can influence plant community dynamics in these cold desert ecosystems. Sagebrush density often increases following drought. Morphological and physiological plasticity of plants in response to highly variable water supplies in semi-arid and arid ecosystems has been shown to be important in determining the ability of a plant to survive and reproduce during and following drought. The semi-deciduous habit of sagebrush, which produces the relatively larger ephemeral leaves in the spring and the smaller perennial leaves in the summer, allows this species to take advantage of cool moist conditions in the spring and continue growth during the prolonged summer drought conditions.

The overall goal of our study was to evaluate the direct effects of drought on growth, nitrogen content, and water relations of a cold desert shrub, Wyoming big sagebrush (*Artemisia tridentata* spp. *wyomingensis* Beetle). Our initial hypothesis was that sagebrush would reduce leaf area, reproductive shoots, ephemeral leaf development, and nitrogen uptake during drought.

MATERIALS AND METHODS

The study was conducted at the Eastern Oregon Agricultural Experimental Range in southeastern Oregon, located 40 miles southwest of Burns. The station lies in the far northern portion of the Great Basin, and is representative of shrub-steppe rangeland ecosystems dominated by sagebrush. The climate is cool, semi-arid desert, characterized by large seasonal variations in temperature and moisture. Winters are cold and wet, summers hot and dry. The mean winter temperature is 31°F, with a daily minimum of 23°F. During summer, temperatures average 64°F, with daily maximum of 80°F. Mean annual precipitation is 11.1 inches (39-year mean), of which 80 percent occurs October through June, the majority as snow.

The study was located in a Wyoming big sagebrush/Thurbers needlegrass habitat type, at an elevation of 4,520 ft. Soils are coarse to fine sandy loam, frigid Orthidic Durixerolls of the Milcan Series. The soil is well drained and is underlain by a duripan at 20 to 40 inches. The study was laid out in two adjacent locations, one containing native vegetation, the second seeded vegetation. The native site contained a 14 percent canopy cover of sagebrush with an understory of Thurbers needlegrass, Idaho fescue (*Festuca idahoensis* Elmer), bluebunch wheatgrass (*Agropyron spicatum* (Pursh) Scribn. & Smith) and Sandbergs bluegrass (*Poa sandbergii* Vasey). The seeded site contained a 5 percent canopy cover of sagebrush with an understory of crested wheatgrass (*Agropyron desertorum* Schult.), planted in the 1960s.

Forty 34 ft^2 circular plots, with a single sagebrush plant in the center, were selected randomly within each location. Criteria used for plot selection were that sagebrush plants had full vigorous canopies greater than 6 inches tall. Precipitation and air temperature were obtained from a U.S. Weather Bureau Station located about 0.6 miles from the study site. Soil water content was measured throughout both growing seasons down to 16 inches. Plant water status (xylem pressure potential), water use (leaf conductance) and leaf nitrogen content were also measured throughout both growing seasons. Plant growth parameters measured were length and dry weight of vegetative terminal and lateral stems and reproductive stems, and dry weight and number of leaves. Perennial, primary ephemeral and secondary ephemeral leaves were separated (Fig 1).

RESULTS AND DISCUSSION

Precipitation during 1988-1989 and 1989-1990 crop years (September - August) was 106 percent and 67 percent respectively, of the long term mean. Soil water content in 1989-1990 was limited in the upper 8 inches, and not available at anytime during the growing season below 8 inches. Sagebrush expressed structural plasticity between the two growing seasons with contrasting levels of soil water availability. Not only did varying water supplies between years influence plant water status, water use, and nitrogen content at peak leaf growth in sagebrush, but also the proportion of different plant structures developed. Water availability during the two growing seasons influenced the partitioning of growth between vegetative and reproductive shoots, leaves and stems, and ephemeral and perennial leaves.

In the drought year, there was a proportionally greater reduction in biomass allocated to reproductive shoots than vegetative shoots on both sites. Biomass allocated to reproductive shoot growth was 8.5-fold greater in 1989 than 1990 for both sites. In another study, supplemental watering in mid summer increased sagebrush inflorescence growth four-fold. Others have also found that perennial plants subjected to environmental stress, including drought, sacrifice reproductive development in favor of maintaining vegetative production.

Plants also allocated a larger proportion of resources for leaf growth than stem growth during the drought; that is, there was a greater reduction in stem development than leaf development for both reproductive and vegetative shoots. For example, leaf biomass decreased 79 percent compared to a 90 percent reduction of stem weight. Lateral stem (Fig. 1) development was non-existent during the drought year. Leaves may have been preferentially developed over stems to increase the energy return on carbon invested. The result of increased leaf:stem ratios in the drought year was that canopies were more densely arranged. This could lead to reduced air movement and increase humidity within the canopy, and thus reduce transpiration during the drought year. The increase in proportion of perennial versus ephemeral leaves on vegetative stems of shrubs on the seeded site would also reduce water loss during the drought year. Drought conditions decreased perennial leaf biomass by 25 percent compared with a 34 percent reduction in ephemeral leaves. In 1989, secondary ephemeral leaf (Fig. 1) development was 11 to 12-fold greater than during 1990. Ephemeral leaves are not as water-efficient as perennial leaves, so the preferential allocation to perennial to leaves would seem a good strategy for water conservation. Changes in resource allocation patterns to different plant parts is an important mechanism for drought avoidance.

Tissue nitrogen concentration in current years' growth was 29 percent less on the seeded site and 18 percent less on the native site in 1990 than in 1989. Others have shown that tissue concentrations of nitrogen declined by as much as 40 percent in water stressed plants compared with well-watered plants. Reduced root growth and nitrate uptake by the root membrane, and reduced nutrient mobility in dry soils limits nitrogen availability.

Response to dry conditions appeared to be different between the seeded and native sites. Stem and leaf growth, and reproductive shoot production were reduced by a greater magnitude on the seeded site than native site during the drought. Stand structure on the seeded site was characterized by a 5 percent sagebrush canopy cover with many sagebrush seedlings entering the stand. The native site contained a 14 percent canopy cover of sagebrush and what appeared to be an even-age stand based on size. No seedlings were observed entering the native stand. The greater reduction of plant growth parameters on the seeded site than the native site were of greater magnitude when water availability was reduced, suggesting that resources other than water were more limiting on the native site. However, although the decline in the relative proportion of growth during drought was greater on the seeded site, growth still exceeded that of the native site in 1990. Increased resource limitation on the native site may be due to increased intraspecific competition and a larger proportion of nutrients tied up in above and below ground biomass on the native site.

CONCLUSION

Drought during the second year did have some predictable effects. Sagebrush water status and use, plant growth and nitrogen content were all less in the drought year compared to the previous year. However, reduced water availability also resulted in sagebrush plants exhibiting a high degree of morphological plasticity. In the drought year compared to the previous year, there was an increase in proportional allocation of resources to vegetative versus reproductive development, in number of perennial versus ephemeral leaves, and in leaf versus stem development. In favorable years, sagebrush is able to increase acquisition of resources by increasing ephemeral leaf area, particularly through secondary ephemeral leaf development, and increasing leaf area through the development of lateral shoots. The potential to rapidly develop leaf area in the spring would increase the ability of sagebrush to compete for resources during optimal growing conditions. It is important for a plant species to maximize its leaf area as early as possible during the growing season to make the most beneficial use of water.

Drought is a common occurrence in the Great Basin. As such, it is important for land managers to understand the specific response of sagebrush to low soil moisture conditions. The reduction in allocation to reproductive shoots seen in the current study indicates that dry years may not be important for sagebrush seed production. However, future research on seed production and viability is necessary to determine the actual contribution sagebrush makes to the seed bank under varying climatic conditions. The findings in this study illustrate several specific adaptations sagebrush possesses that enable it to survive in a semi-arid environment. The ability to alter the amount of biomass allocated to various plant parts in response to drought increases sagebrush's ability to compete successfully with other species for limited soil resources.

Figure 1
Artemisia tridentata vegetative shoot; (1) primary ephemeral leaf, (2) secondary ephemeral leaf, (3) perennial leaf, and (4) lateral shoot.