QUAKING ASPEN (*POPULUS TREMULOIDES*) GROWTH RATE WITHIN THE BLACK HILLS OF SOUTH DAKOTA

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ABSTRACT

Average annual growth rate of quaking aspen (*Populus tremuloides* Michx.) was measured in the Black Hills of South Dakota at locations where some method of aspen treatment (slash, clear fell coppice, hinging, conifer removal, fencing, or combinations of these treatments) had been in effect for 10-14 years. Aspen suckers in the Black Hills require protection from ungulate browse to reach a size great enough to perpetuate the stand. Knowing the time required for protection would provide land managers information to increase aspen survival. The Black Hills average annual growth rate was 20 cm in height and 2.2 mm in diameter. Average annual increases in height ranged from 15 cm per year in the Northern Black Hills to 27 cm in the Central Black Hills. At least twenty years of protection from ungulates would be required for aspen to reach heights of 4 m at a growth rate of 20 cm per year. General consensus is aspen suckers should reach 1.5 m in height to survive browsing from domestic livestock and 2-4 m in height to survive browsing from wild ungulates. Aspen suckers also need to reach 4 cm diameter at breast height to survive extreme elk (*Cervus canadensis*) browsing pressure. Normal growth in the western U.S. has been estimated to be 40-50 cm height per year and 4-5 mm diameter per year. At the normal growth rate, 8-10 years would be required to reach the minimal survival size (1.5-2 m), but aspen in the Black Hills may require browse protection for twice the time.

Keywords

browsing, net growth rate, ungulate, wildlife

INTRODUCTION

The abundance and distribution of quaking aspen (*Populus tremuloides* Michx.) is declining throughout the western United States (Kay 1997; Bartos and Campbell 1998a, 1998b; Bartos 2001; Kaye et al. 2003) and possibly within the Black Hills. Severson and Thilenius (1976) reported that 5% of the total land surface of the Black Hills and Bear Lodge Mountains was occupied by aspen, while Keyser et al. (2005) reported that aspen was rare and occupied about 4% of the forested land base in the Black Hills. DeBlander (2002) estimated that aspen occupied 3% of the total forest land area, and Blodgett et al. (2017) reported 3% of the cover of the Black Hills was aspen. While these studies suggest an aspen decline in the Black Hills, (Walters et al. 2013) reported that 8% of 1.16 million acres of the Black Hills contained aspen or birch, aspen represented about 10% of all trees 1 inch or greater diameter (DBH), aspen had a negative net average annual growth due to a high mortality rate, and the abundance of aspen to the overall tree species diversity in the Black Hills was predicted to decline.

Aspen, a disturbance-dependent species, usually responds with vegetative root suckering after fires (Bartos 2001; Jones and DeByle 1985; Brown and DeByle 1987). Fire removes conifer competition, stimulates aspen root systems to produce suckers, and fire intensity can influence suckering (Schier et al. 1985; Keyser et al. 2005). Fire suppression used as a management practice is partially responsible for aspen decline because it alters the regeneration processes of aspen (Bartos 2001; Kaye et al. 2003). Aspen regeneration failures following fire have been reported (Schier et al. 1985; Bartos et al. 1994; Romme et al. 1995; Kota and Bartos 2010) because of excessive ungulate browsing of the regeneration and additional direct and indirect herbivore impacts (Heady and Child 1994). Past Black Hills forest management has included fire suppression, aspen stand conversion to conifer, and grazing by wildlife and livestock (Kranz and Linder 1973). Ungulate impacts to aspen suckers and a decline in fire reduce survival of aspen on the landscape (Bartos et al. 1994; Shepperd et al. 2006; Kota and Bartos 2010). Keyser et al. (2005) observed that 58% of all live aspen sprouts had been browsed following a fire (Jasper fire) within 4 years in the Southern Black Hills. And for the same areas, Kota and Bartos (2010) reported that 78%-79% of aspen suckers were browsed for two consecutive years.

Growth rates of aspen are generally determined by two methods. The first method uses stem height of suckers and age of stem or time since a disturbance or treatment (since sucker emerged) to reach 1.5-4 m, the heights of the apical meristem beyond what ungulates can browse. The second method uses site index curves which are based on trees beyond the small sucker stage, dictated by dominant trees or age classes in stands and often determined by region (Jones and Schier 1985). The second method often omits scrutiny of growth and age before trees reach 4 m height or greater during the first 20 years of life.

Ungulate browsing is expected to cause many Black Hills aspen stands to fail after disturbance (Keyser et al. 2005; Kota and Bartos 2010) unless protection is provided. The main objective of this study was to determine the average annual growth rate of aspen suckers in the Black Hills of South Dakota. Net growth rates included the height of stem growth per year minus any dieback, direct and indirect browsing impact, disease, damage or loss from weather events, or competition with adjacent vegetation. A second objective was to estimate the number of years required for aspen to reach a minimum height or diameter that is beyond the risk of browsing.

METHODS

Study Sites. The project area and populations of interest were four geographical areas within the Black Hills of South Dakota and include the Northern, Central, Southern Black Hills and Custer State Park (Figure 1). These four areas are in Lawrence, Pennington and Custer Counties. Elevation of all sample sites ranged from 1370 m to 2020 m. Canopy tree cover varied between 0-93%. Suckers were collected at locations where previous aspen treatments had occurred within the past 20 years (Figure 1). Most treatments had been in place for 10-14 years and included slash, clear fell coppice, hinging, conifer removal, fencing, or combinations of these treatments (Mergen 2018). Fence heights were 0.9 -1.2 m (livestock fence, i.e., barb-wire) to 1.8-2.7 m (wooden buck and pole fence), and 2.4 m (wildlife, mesh wire fence) and were often installed following wildfire.

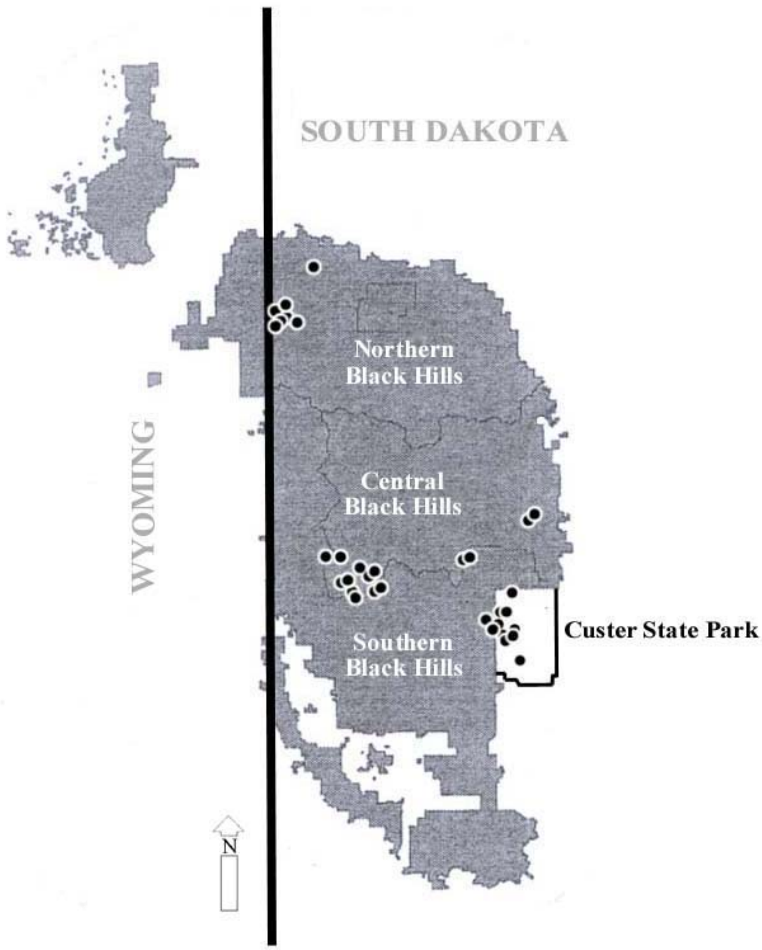

Figure 1. Circles indicate location of sample sites throughout the Black Hills of South Dakota. Some circles overlap because some sites had adjacent treatments.

Sampling Procedure and Data Collection. Forty-three treatment sites 0.2-40 ha were visited between June 7 and September 17, 2016. Each sample location contained some type of past aspen treatment, and suckers were collected that were protected from browsing animals to some degree over the past 10-14 years. The first 1-7 suckers encountered were collected at 43 sites and only if each had an easily defined terminal leader (Keigley and Frisina 1998). Overall, 158 aspen suckers were collected throughout the Black Hills. Sucker stems were cut at the soil surface with a shear. Total sucker height measurements were recorded in cm for the primary stem. Diameter of each sucker was measured in mm with a caliper 3 cm above the cut to reduce the influence of the shear deforming the stem. Since stems were not circular, a short diameter and a long diameter were measured and averaged.

After growth measurements had been recorded, a 2-5 cm section of each stem bottom was cut off and labeled with tape to identify the site and tree number. Each section was air dried for several months and then heated in an oven at 200 degrees for thirty minutes to dry completely the stem samples. Each sample was then placed in water containing red food color dye (Spice Supreme brand, FD&C Red #40) and allowed to absorb the dye for 10-15 minutes on both cut ends. Cut ends of the dyed stem were air dried and sanded on an electric sander with 120 and 220 grit sandpaper to level and smooth the stem. Stems were then viewed under a dissecting microscope (8-32 power magnification), and growth rings were counted to determine age.

Data Analyses. Average annual growth rate was determined for each aspen sucker (n=158) by dividing the total height measured by total number of annual rings counted, less the current year (2016). The length of stem that grew in 2016 was subtracted since some suckers may not have completed their growth in 2016. A site average growth rate was calculated as well as a Black Hills average rate. Growth rate averages for height and diameter among four areas were then analyzed using GLM one-way ANOVA. LSD tests were used to determine significant differences (SAS 1988). The number of years for stems to become recruitment stems, i.e., able to grow above browsing height by ungulates, was determined based on our annual growth rates.

RESULTS

Sucker ages ranged from 2 years to 27 years. Annual growth rate for aspen suckers within the Black Hills was 20.1 cm (7.9 inches) overall and varied from 15.0 cm in the Northern Black Hills, 17.7 in Southern Black Hills, 22.3 cm in Custer State Park, to the greatest of 27.1 cm in the Central Black Hills (Table 1). The average annual growth rate for the Central Black Hills was significantly greater ($P \leq 0.01$) than that for the Northern and Southern Black Hills, and similar to that for Custer State Park. Stem diameters ranged from 15 to17 mm. Annual diameter increases were 2-3 mm and were similar among the four areas ($P \leq 0.4$).

Based on our growth rates, aspen suckers in the Black Hills would need 7 to 13 years to grow to a height of 2 m and 15-33 years to reach stem heights of 4-5 m and be large enough to survive extreme elk browsing. Based on our measured rates, the time range would be 15-19 years in the Central Black Hills to as long as 27-33 years in the Northern Black Hills (Table 1). It would require 15-19 years for stem diameters to reach 4 cm diameter.

Table 1. Aspen sucker measurements collected in 2016 in the Black Hills of South Dakota, and include sucker height, diameter, number of annual rings, growth rate, and time to grow beyond minimum browse risk. The 158 stem values were summarized into 43 site averages that were then averaged by populations of interest. Means are shown with standard errors in parenthesis and n = number of sites. Growth rates among the four areas (entire Black Hills excluded) were analyzed; different letters indicate significantly different growth rate values ($P \leq 0.01$).

Plant characteristic	Entire Black Hills n = 43	Northern Black Hills n = 8	Central Black Hills n = 7	Southern Black Hills n = 15	Custer State Park n = 13
Stem growth rate ($cm \bullet yr^{-1}$)	20.1 (1.3)	15.0 (1.2) b	27.1 (4.8) a	17.7 (1.6) b	22.3 (1.8) ab
Diameter growth rate ($mm \bullet yr^{-1}$)	2.2 (0.1)	2.2 (0.2) a	2.6 (0.4) a	2.1 (0.1) a	2.2 (0.2) a
Total stem heights (cm)	137.4 (6.1)	115.5 (15.1)	155.8 (14.5)	118.8 (7.2)	162.4 (9.9)
Average number of rings	8.2 (0.5)	8.7 (2.2)	6.8 (1.0)	8.3 (0.7)	8.4 (0.5)
Average diameter (mm)	15.8 (0.6)	15.7 (2.1)	14.8 (0.9)	14.9 (0.8)	17.4 (0.8)
Years to grow 2-3 m at given rate (become recruitment stem)	10-15	13-20	7-11	11-17	9-14
Years to grow 4-5 m at given rate (survive extreme elk browse)	20-25	27-33	15-19	23-28	18-22
Years to grow 4 cm diam. at given rate	18	18	15	19	18

DISCUSSION

Average annual growth rates are seldom reported directly in the literature. Instead aspen stem data are generally displayed as stem height and number of years since disturbance. Most of Jones and Shier (1985) data from Arizona had growth rates of 30-75 $cm \bullet yr^{-1}$ with some reaching 150 $cm \bullet yr^{-1}$. Keyser et al. (2005) data collected from the 2000 Jasper burn in the Southern Black Hills reported stem heights measured 4 years post-fire; these results were 6.2 cm • yr^{-1} in unburned, 9.8 cm•yr^{-1} in low burn, and 14.4 cm • yr^{-1} in high burn areas. These growth rates were about 3-12 cm less (high burn-unburned, respectively) than the 17.7 cm Southern Black Hills value (Table 1), but their data were not collected within past treatment sites that provided some level of browse protection. Shepperd (2004) reported that sucker data collected in Arizona increased to greater height in burned plots compared to unburned and they increased nearly 2.5-3 m in height in 5 years (250 or 300 cm/5 yr), a growth rate of 50-60 cm • yr^{-1}.

Aspen suckers are at greatest risk of being browsed until they exceed 1.5 m height from domestic animals (Sampson 1919; Smith et al. 1972) and 2-4 m from wild ungulates (DeByle 1985; Kimble et al. 2011). Recruitment stems measured in Yellowstone northern winter range were suckers that had grown to heights (>2 m ht. and <5 cm diam.) and survived browse to perpetuate an aspen stand (Kimble et al. 2011; Kauffman et al. 2010). Sucker heights able to survive extreme elk (*Cervus canadensis*) browsing pressure observed in Arizona were 4-5 m tall and >4 cm diam. (Shepperd 2004; Shepperd and Fairweather 1994). Eight to ten years of normal growth were determined necessary for suckers to attain heights of 4-5 m and diameters of 4 cm in most cases, which would be large enough to be protected from the most extreme elk browsing pressure (Shepperd 2004; Shepperd and Fairweather 1994). This would result in an annual average growth rate of 40-50 cm • yr^{-1}. Black Hills averaged growth rates were less than 30 cm•yr^{-1} within past treatment sites that offered some level of browse protection. The entire average Black Hills growth rate was 2-2.5 times less than average growth rates of 40-50 cm • yr^{-1} observed elsewhere. Suckers would also need 15-19 years of protection in the Black Hills to reach 4 cm diameter.

The Black Hills aspen suckers were from areas of past treatments that were 10-14 years old and provided some protection from browse. The differences in growth rates among the four areas are likely the results of elevation. Greater annual growth rates for the Central Black Hills and Custer State Park were at sites with elevations between 1370-1650 m (4570-5500 ft) while the Northern and Southern Black Hills sites were between 1620-2020 m (5400-6730 ft). Covington (1975) reported aspen trees leafed out up to 5 weeks earlier and senesced 3-5 weeks later at lower elevations in New Mexico. The 20 cm per year growth rates may be an optimistic rate for the Black Hills since these rates were determined from areas that were treated and offered some form of browse protection. Growth rates may be less if data are collected from untreated aspen stands that lack any browse protection. Protection from browse in the Black Hills may require at least twice the time as reported in other areas of the western U.S. to grow to size beyond browse risk and able to perpetuate an aspen stand.

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