Total Available Carbohydrates in Serviceberry After Late Summer and Fall Burning

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Abstract—Total available carbohydrate (TAC) storage and depletion was measured in late summer and fall burned and unburned serviceberry (*Amelanchier alnifolia*). The purpose of the study was to assess the influence of late season prescribed fire on the vigor of serviceberry, a key browse species on white-tailed deer (*Odecoileus virginianus ochrourus*) winter range in northeastern Washington. All plants displayed similar TAC cycles through the first growing season following treatment. TAC levels in stems were highest prior to bud activity and declined during the early stages of growth (March, April, May). The low levels of stem TAC coincided with periods of maximum stem growth. Roots had the highest TAC concentrations prior to dormancy, then declined as stem elongation progressed to mid-season. After maximum stem elongation, root TAC levels increased significantly through the remaining growing season. Late summer burned plants displayed immediate new growth following treatment and advanced phenology during the first growing season in contrast to fall burned and control plants. The first year growth of fall burned shrubs was delayed until after control plants had initiated stem elongation. Neither burn treatment had major impacts on carbohydrate storage nor vigor of shrub growth.

Introduction

Serviceberry (*Amelanchier alnifolia*) is a preferred winter browse for white-tailed deer on many habitat types of northeastern Washington and adjacent Idaho. The shrub is common in late stages of forest vegetation succession in the Northern Intermountain Region but is most abundant in the early stages of vegetation development following fire. Serviceberry is a prolific resprouter following fire (Leege and others 1971; Miller 1976). Most of the prescribed burning to enhance deer winter habitat in northeastern Washington is conducted during the fall season. The time of burn varies according to fuel and weather conditions, but commonly burns are conducted prior to onset of winter dormancy in many of the browse species of the area. Concern was raised about the potential influence of late summer and early fall burning on browse recovery if browse species were burned while still in active growth at the time of the burn. A key physiological function in woody plants is the storage of available carbohydrates produced by photosynthesis in excess of plant maintenance (Chapin and Shaver 1990; Coyne and others 1995). This function provides an essential source of energy for plant survival during dormancy and production of plant tissue during early spring growth when carbohydrate utilization exceeds photosynthetic production. Interruption of the normal storage cycle of reserves in the later stages of growth would potentially impact the survival, vigor, and vitality of plants. Indication of such impact should be apparent during the first growing season following treatment.

The objective of this study was to determine the trends in depletion and storage of total available carbohydrates within various parts of serviceberry shrubs during the first growing season following canopy removal by late summer and fall burning.

Methods

Study Area

The study area is located on the Little Pend Orielle Wildlife Recreation Area in Stevens County, northeastern Washington. The area is controlled and managed by the Washington State Game Department by permission of the United States Fish and Wildlife Service of the Department of the Interior who retains ownership. Location is 18.5 km east-southeast of Colville, Washington. Annual precipitation averages 40 cm. Snow provided approximately 32 percent of this moisture. Snow can be expected by November and commonly remains on the ground from December through February. White-tailed deer (*Odecoileus virginianus ochrourus*) occupy the area from mid-November to mid-March. Average daily winter temperatures during this time range from 20 to 35 °F. Summers are warm, and sunny with regularly occurring light rainfall throughout the summer. The elevational range of the area is 730 to 775 m. Soil characters are strongly influenced by glacial till composition overlain by erosionally deposited fines. The Douglas-fir/mallow ninebark (*Pseudotsuga menziesii*/*Physocapus malvaceus*) plant association represents more than 70 percent of the area's vegetation (Williams and others 1990). Serviceberry averages less than 9 percent canopy cover throughout the study area. While not the most abundant browse species of the winter range, this species is designated a key management species because of its low abundance and high browse preference to white-tailed deer.

In: McArthur, E. Durant; Fairbanks, Daniel J., comps. 2001. Shrubland ecosystem genetics and biodiversity: proceedings; 2000 June 13–15; Provo, UT. Proc. RMRS-P-21. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

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Field Methods

Thirty-six shrubs were selected for early August and mid-October burn treatments. Twenty-five additional shrubs were selected as control plants. Early August represents a physiologically active mature shrub having achieved maximum stem elongation and supporting maximum leaf area. Mid-October represents a fully dormant, leafless mature shrub condition. Pre-burn characteristics of the shrubs are shown in table 1. The biomass of each shrub was calculated using regression equations relating biomass to individual stem diameter at ground level length, and total canopy volume of the plant. Total canopy volume was calculated using the formula for a cylinder where the maximum diameter and the average height of the canopy are used as dimension variables.

Each shrub was burned individually in the treatments. Additional fuel was inserted into the canopy of each shrub in order to achieve a complete canopy removal burn. This fuel consisted of twenty 2 cm x 2 cm x 120 cm 200 g mill strips or 8 kg of air dry straw.

The control shrubs served as the base for comparison to plants in the burn treatments. Four stems of each control plant were labeled with small metal tags for repeated observation to characterize phenology and growth. Length measurements in mm were made from bud scars at the base of the current year twig to the tip of the true-terminal bud.

Laboratory Methods

Burned and control plants were excavated during the first growing season following treatment. Sampling was conducted according to the specific phenological stages of late winter dormancy, active growth, end of stem elongation, and total leaf senescence. Subsamples of small roots (less than 7 mm in diameter), large roots (greater than 7 mm in diameter), root crowns, current year stems, and second year wood were collected. Samples were placed in plastic bags, labeled, immediately frozen on dry ice, then transported to the laboratory and stored in a freezer until freeze-dried. The freeze-dried samples were ground in a Wiley mill through a 2 mm screen and stored in airtight jars at 68 °F until analyzed. Total available carbohydrates (TAC) will be the preferred term used throughout this paper to identify the nonstructural reserve component which can be readily metabolized by the plant (Weinmann 1947; McConnel and Garrison 1966). The TAC was extracted from the ground plant samples using 0.2N sulfuric acid as described by Smith and others (1964). This method hydrolyzes TAC to reducing sugars that can be measured quantitatively by the Shaffer-Somogyi copper-iodometric titration method outlined by Heizne and Murneek (1940). Data were subjected to analysis of variance and Duncan's new multiple range test within the GLM procedure of the Statistical Analysis System, 1979 Edition (Helwig and Council 1979). Significant differences between means are interpreted at the 0.05 level.

Results and Discussion

Phenological Development

Serviceberry plants typically remain dormant through the end of February. By early March, plants begin to enter the active bud stage. This progresses to nearly 100 percent expression of the active bud stage by end of April. At this time, a small percentage of the plants begin to enter the bud burst stage and express anthesis. By mid-May, all plants had entered the bud burst stage and show anthesis and the beginning of stem elongation. The maximum rate of stem elongation occurs from early-May to mid-June. Maximum leaf area generally is achieved by mid-June and will persist as a physiologically active leaf set until mid-July. After this point in time, insect depredation, water and heat stress, and fungal disease begin to cause varying degrees of leaf senescence. Maximum stem elongation is achieved by early August. Leaf senescence started in ernest at the end of August and is complete by early October. Leaf fall of senesced leaves may extend into mid-November.

The phenological development of the burn treatment plants was similar in timing and pattern to that of the control plants with some important exceptions. All plants burned in late summer regenerated a significant amount of new stem and leaf growth within 1 month of the treatment. The new leaf sets appeared vigorous and physiologically active later into October. Fall burned and control plants did not initiate new fall growth. In the first growing season following treatment, all late summer burn plants initiated growth well in advance of the fall burned and control plants. The late summer burned plants became bud active in late February with stem growth initiating by mid-March and

Table 1—Average total available carbohydrates (TAC) percentages across phenological stages for five plant parts of unburned control plants.

	Phenological stage			
Plant part	Bud active	Anthesis	Maximum stem elongation	Entering winter dormancy
Current year stem	***	11.7 a	8.9 b	8.5 c
Second year stem	9.2 d	8.1 e	8.1 e	8.3 e
Root crown	8.7 e	7.2 f	7.6 g	9.3 d
Large roots	9.5 d	9.4 d	9.3 d	9.9 e
Small roots	7.3 f	7.8 g	9.4 d	7.4 f

***Current year growth had not been initiated by this date.
Means followed by the same letter are not significantly different at the 5 percent level of probability.

rapid stem elongation by early-April. Anthesis did not occur in plants of either burn treatments. Both fall burned and control plants followed an identical phenological pattern.

TAC Levels

The TAC depletion and storage cycle in the control plants is shown in table 1. Generally, all stems were at high TAC levels at the beginning of the bud active stage. TAC levels in current and second year wood peaked at the time of anthesis, then began a sharp decline as stem elongation accelerated. TAC levels of these plant parts stabilized by the end of the stem elongation period. These peaks in stem TAC coincide with declining levels of TAC in roots, root crowns, and older stem portions suggesting that stored TAC in these plant parts is being translocated to new growth sites in the canopy. After anthesis, the TAC levels in roots and root crowns began to progressively increase through the remaining growth period. All below ground parts combined, had higher concentrations of TAC than the aerial portions of the plants after midseason.

Current year growth of burned plants was the only canopy portion available for comparison to the control plants. The seasonal trends in depletion and storage of TAC plants of both burn treatments were generally similar to the control plants (table 2). A significant reduction in current year stem TAC of all burned plants occurred after anthesis, leveling off at the end of stem elongation period. No significant differences were found in the TAC trends of all treatment plants. Small roots of late summer burn shrubs exhibited a continual decline with a significantly lower level of TAC by early October. Small roots of late summer burned plants began the season at higher TAC levels than plants in other treatments. Excavation of these roots indicated that they were actively growing at the time. Garrison (1971) stated that stored carbohydrates are not affected by top removal in many shrubs because small roots store the bulk of carbohydrates needed by the plant. Large root TAC remained fairly constant for the control and fall burned shrubs with a small upward trend after anthesis and maximum stem elongation. The late summer burned plants showed a statistically significant increase in TAC levels between the end of stem elongation and mid-October dormancy. Root crown TAC remained constant for all burned shrubs throughout the season.

Coyne (1969) felt maximum carbohydrate reserves are not attained until a plant completes its annual life cycle and that maximum plant vigor depends upon the level of TAC storage. Interruption of this cycle by burning in early August, prior to completion of serviceberry's growing cycle did not appear to reduce serviceberry vigor during the first growing season following treatment. Roots had the highest concentration of TAC prior to dormancy. Therefore, as long as the root component of the plant is not damaged by the late summer fire, the crown portion is not requisite to the plant survival. Coyne and others (1995) have suggested that fall growth may tap stored reserves of the plant and stress the plant to a point of low vigor, especially if repeated cropping of the new growth is taking place. The fall growth of late summer burned plants may potentially reduce TAC root levels to the point of affecting the subsequent year's canopy growth. Continual crown removal has been shown in other studies (George and McKell 1978) to affect root reserves and ultimately kill the plant. However, this was not evident in the trends of TAC following treatment nor growth of plants in this study.

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Table 2—Average total available carbohydrates (TAC) percentages across phenological stages for four plant parts of late summer and fall burned plants during the first growing season following treatment.

		Phenological stage			
Plant part	**Burn treatment**	**Bud active**	**Anthesis/ stem elongation initiated**	**Maximum stem elongation**	**Entering winter dormancy**
Current year stem	Late summer	12.3 a	10.2 b	8.1 c	7.4 c
	Fall	***	10.7 b	8.3 c	8.2 c
Root crown	Late summer	8.5 a	8.5 a	7.8 b	7.9 b
	Fall	8.2 c	8.2 c	8.8 d	8.6 d
Large roots	Late summer	7.9 a	7.8 a	7.1 b	9.5 c
	Fall	8.4 d	7.6 a	8.3 d	9.0 e
Small roots	Late summer	9.4 a	8.4 b	7.8 c	7.1 d
	Fall	7.3 d	8.0 c	7.4 d	8.5 b

***Current year growth had not initiated in this treatment by this date.

Within each plant part category, means shown in the 2 treatment rows followed by the same letter are not significantly different at the 5 percent level of probability.

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