Fall 2000

Burning Characteristics of Big Leaf Maple, Red Alder, and Black Cottonwood Leaves

Elizabeth Ralston

WESTERN
WASHINGTON UNIVERSITY

An equal opportunity university

Honors Program

Bellingham, Washington 98225-9089
(360)650-3034 Fax (360) 650-7305

HONORS THESIS

In presenting this Honors paper in partial requirements for a bachelor's degree at Western Washington University, I agree that the Library shall make its copies freely available for inspection. I further agree that extensive copying of this thesis is allowable only for scholarly purposes. It is understood that any publication of this thesis for commercial purposes or for financial gain shall not be allowed without my written permission.

Signature [signature]

Date December 12, 2000

Burning characteristics of big leaf maple, red alder, and black cottonwood leaves

Elizabeth Ralston
Biology Department, Western Washington University, Bellingham, Washington
Senior Honors Project
December 12, 2000

Abstract

The leaves from three Northwest deciduous trees were burned to compare flammability of nonwoody fuels. The following characteristics were measured in a completely randomized design ANOVA: maximum flame height, flame time, ember time, burn time, percent combusted, and mean rate of weight loss. The burning characteristics examined address important aspects of nonwoody fuel flammability in deciduous forests. My data indicated that alder, cottonwood, and maple leaves create a consumable fuel load that could support a moderate intensity, sustainable fire. The data were compared to a previous study of burning characteristics needles of Pacific Northwest conifers (Fonda et al. 1998). Deciduous leaves are as flammable as ponderosa pine needles.

Introduction

In June 1999, Olympic Pipeline leaked ~866,000 liters of gasoline into Whatcom Creek in Bellingham, Washington, that ignited a devastating fire. Contrary to a normal wildfire, in this case the river itself was the source of the flames. The fire burned with explosive intensity, especially on the left side. The western one kilometer of the burn zone supports three main deciduous tree species: big leaf maple *(Acer macrophyllum)*, red alder *(Alnus rubra),* and black cottonwood *(Populus tricocarpa).* Red alder, big leaf maple, and black cottonwood do not depend on fire for their livelihood, thus they are generally regarded as fire invaders or avoiders (Table 1). The Whatcom Creek fire presented a unique opportunity to examine the effects of a moderate intensity fire on these deciduous species in a riparian zone (Table 1). My study focused on the flammability of the leaf litter that these three species could contribute to a fire environment.

Weather and fuel moisture content have always been considered important factors for forecasting fire conditions, but little attention has been given to energy differences in fuels (Davis 1959). Mutch (1970) presented experimental results that suggest natural chemical characteristics are also important in determining flammability of plant communities. He conducted combustion tests with litters of eucalyptus leaves and ponderosa pine needles as examples of fire-dependent species. He also burned tropical hardwood leaves as an example of a non-fire dependent species. Mutch hypothesized that natural selection has favored development of characteristics that make fire-dependent communities more flammable than non-fire dependent communities (Mutch 1970). Specifically, fuel chemistry of litter in fire-dependent communities should be greater than litter from non-fire dependent species such as maple, alder, and cottonwood.

Red alder was previously classified as a fire invader, which signifies that it does not usually inhabit fire prone communities (Agee 1993). Red alder stands typically lack flammable understory debris and are often found on moist sites (Fowells 1965). It is an early pioneer, seral species that is common on disturbed areas. Red alder benefits from fire as it regenerates on the post-fire site via seeds. The tree generally flowers between late February and early May (Schopmeyer 1974). Thus, the leaves were in full bloom at the time of the Whatcom Creek fire.

Black cottonwood was also classified as a fire invader (Table 1, Agee 1993). It is a pioneer species that commonly establishes itself on disturbed alluvium sites (Hansen et al 1988). Cottonwood flowers are produced in catkins just before or during leaf emergence, typically in March to May (Kennedy 1985). Therefore, at the time of the Whatcom Creek fire, cottonwood leaves and flowers were in bloom. Information is scarce about the flammability of cottonwood foliage and leaf litter.

Big leaf maple is a fire endurer (Table 1). Bigleaf maple's ability to resprout from stem, root crown, or roots after top-kill fire designate it as an endurer (Agee 1993, Fonda 2001). Bigleaf maple commonly grows where soils are moist, especially on deep alluvial soils near streams (Fowells 1965). Flowering and leaf emergence occur simultaneously in late March or April (Haeussler 1986). Big leaf maple is not fire dependent, thus little is known about its leaf or foliage flammability.

All three species responded positively to the intense fire at Whatcom Creek as an environmental factor in their normally stable lowland riparian zone (Fonda 2001). Although red alder and black cottonwood were previously classified as invaders, recent data suggest that they at least endure low to moderate intensity fires (Table 1). Bigleaf maple, previously deemed an endurer, also endures and perhaps resists fires of low and moderate intensity, depending on tree size and actual fire intensity (Fonda 2001). All three species endured moderate to high intensity fire in the Whatcom Creek lowland riparian zone (Fonda 2001).

I studied the leaves of the three deciduous species as indicators of flammability. Flammability has four major components: ignitability, combustibility (intensity), sustainability, and consumability (Martin et al. 1994). Flame height indicates intensity. Flame time, ember time, and burn time describe the sustainability of the fire. Percent consumption and mean rate of weight loss relate to consumability of the fuel (Fonda et al. 1998).

The Whatcom Creek fire presented an opportunity to test if deciduous leaves from a normally non-fire dependent community were highly flammable. My research concentrated on the following questions: 1) Were differences in burning characteristics significant among the three species? 2) How does the flammability of deciduous leaves compare to needles of coniferous species common in the Pacific Northwest, some of which are considered highly flammable?

Methods

I followed the methods in Fonda et al. (1998). The experiment was designed as a completely randomized design ANOVA, with the species as the treatments. The significance level was set at 5% before testing began. I burned 10 samples of each species, for a total of 30 burns.

Species and collection sites are listed in Table 1. Leaves from each species were gathered from several locations at each site, and placed in a drying room until needed. Leaves were cleaned of debris and each leaf type was separated into ~15 gram samples. As needed, they were placed in aluminum trays in a 100°C oven for 72 hours. Samples were removed from the ovens, and weights were adjusted by removing leaf matter so that the sample to be burned weighed 14.9 to 15.5 grams.

The fire chamber was 1 m^2 by 3 m tall, with a four-story exhaust chimney (Fonda et al. 1990). A fan in the chimney controlled air movement at mean air velocity at 9.96+0.9cm sec^{-1} (Fonda et al.1998).

The fuel bed was arranged in a pile no higher than 4 cm on the chamber floor. The pile was placed behind a semicircle formed by a 40 cm string dipped in xylene. Both ends of the string were ignited, and two timers were started when leaves first ignited. Maximum flame height was judged by comparing the highest point reached by flames against a meter stick attached to the back wall of the chamber.

The room lights were extinguished after maximum flame height was read, to judge flame and burn times. Flame time was determined by stopping the first timer after all flames were extinguished. Burn time was determined by stopping the second timer when the last ember was extinguished. Ember time was total burn time minus flame time.

Burned string was removed from remnants of the burn. Percent fuel combusted was calculated by weighing the ashes and dividing consumed weight by initial weight. Mean rate of weight loss was calculated as mg lost over burn time.

Data for regional Washington conifers in Table 3 were made available from Fonda et al. (1998). They were compared to the results of alder, cottonwood, and maple burning characteristics by a completely randomized design ANOVA with a 5% significance level.

Results

Flame heights were not significantly different for maple and alder leaves (Table 2). Both were significantly higher than cottonwood flames. Maple leaves had the three highest flames (90 cm max) of the 30 burns in this study, and all maple maximum flame heights were above 70 cm. Maximum flame height for alder leaves was between 60 and 78 cm. The maximum flame height for cottonwood leaves was in the range of 40-55 cm, except for one sample (74 cm).

The flames for cottonwood lasted significantly longer than alder and maple flames, which were not significantly different (Table 2). In eight out of ten cottonwood trials, flame time surpassed 60 seconds. Four of the ten burns exceeded a flame time of 90 seconds, with a maximum of 104 seconds. Maximum flame time for alder was 73 seconds, and it was never less than 34 seconds. Maple flame time fell in the range of 28 to 47 seconds.

Ember time did not differ significantly among the three species (Table 2). Three of 30 total burns were less than 90 seconds. Ember time exceeded 250 seconds in six of 30 total burns. Ember time was in the 90-250 second range for 70% of all burns.

Burn times did not differ significantly among the three species (Table 2). Burn time exceeded 350 seconds for five of 30 total samples. Four of 30 samples had burns shorter than 150 seconds, although none ever lasted less than 106 seconds. Thus, 70% of all burns lasted between 150 and 350 seconds.

Significantly more alder fuel was combusted than the other species. All samples of alder leaves combusted more than 83%, and seven trials combusted over 90%. Maple leaves combusted significantly less fuel than alder samples. Maple burned at a maximum combustion of 87%, and trials were never less than 82% combusted. Cottonwood samples combusted significantly less fuel than alder and maple. Lowest cottonwood fuel combustion was 69%, and exceeded 85% in only one instance.

The difference in mean rate of weight loss was not significant among the three species. Two of 30 total trials exceeded 100 mg/sec, and both were maples. Six of 30 total trials were <40 mg/sec. Thus, 73% of the total trials fell in the range of 40-100 mg/sec.

Discussion

Flame heights were not significantly different for maple and alder leaves, but were higher than cottonwood flames (Table 2). The flames for cottonwood lasted significantly longer than alder and maple flames. Flame times were not significantly different for alder and maple. Significantly more alder leaf material was combusted than the other species. Significantly less cottonwood fuel was combusted than alder or maple. There was no significant difference in ember time, burn time, or mean weight loss among the three species (Table 2).

The burning characteristics of deciduous leaves were compared to coniferous needles (Fonda et al. 1998) of common Pacific Northwest trees, to determine relative flammability of leaves of regional tree species (Table 3). Big leaf maple, red alder, and cottonwood leaves had three of the top four highest flames of the Northwest species (Table 3). Big leaf maple had significantly higher flames than any other deciduous or coniferous species. The deciduous species had three of the four shortest flame times of the northwest species (Table 3). Red alder and big leaf maple flames burned significantly a shorter time than all other species. The deciduous species accounted for three of the five longest ember times, and three of the five longest burn times (Table 3). The ember and burn times for the deciduous species were significantly higher than Douglas fir and western hemlock. Red alder, big leaf maple, and cottonwood were three of the four highest in terms of percent fuel combusted (Table 3). Red alder and ponderosa pine had the highest percent fuel combusted of any species, and were not significantly different. Big leaf maple and cottonwood had the next highest percentages of fuel combustion. The three deciduous species had a faster rate of weight loss than three out of four coniferous species (Table 3). The deciduous species had higher percent fuel combustion, and combusted at a faster rate, than most coniferous species.

The deciduous species had higher, shorter flames, longer ember and burn times, higher percent fuel combustion, and higher rate of combustion than most coniferous species. The flame height data characterize the deciduous leaves as capable of supporting a more intense fire than most coniferous needles. Short flame time, and long ember and burn times are characteristics of a sustainable fire. Burning in deciduous leaves is therefore sustainable. A high percentage of fuel was combusted for these deciduous species, at a high rate of weight loss, which indicate good fuel consumablity. My data indicate that alder, cottonwood, and maple leaves create a consumable fuel load that could sustain a moderate intensity fire.

Ponderosa pine was the most flammable coniferous species (Table 3). The leaves of these three deciduous species along Whatcom Creek had burning characteristics not often significantly different from ponderosa pine needles (Table 3). The deciduous leaves are also highly flammable. My results challenge the hypothesis that non-fire dependent communities are less flammable than fire-dependent communities (Mutch 1970). The deciduous leaves of trees native to a non-fire dependent riparian zone were as flammable as fire-dependent ponderosa pine needles (Table 3).

Further information on burning characteristics of needles and leaves is scarce. Contrary to the data in Table 2, the USDA Forest Service suggests that red alder foliage and leaf litter is lowly flammable (1998). Red alder had the highest rate of combustion of the three species, indicating good fuel flammability. Tall flames and short flame time suggest that alder can support an intense, sustainable fire.

The only other data on burning characteristics of non-fire dependent, deciduous species come from an examination of tropical hardwood leaves (Mutch 1970). Tropical leaves had a 60 cm flame height, which was higher than cottonwood, but lower than alder and maple (Table 2). About 19% of the tropical leaves were consumed by fire, which is far less than the lowest percent fuel combusted of the three species tested in this study (Table 2). Other burning characteristics Mutch tested were not comparable to the methods I used.

The flammability realized by the leaves during the Whatcom Creek fire, however, was lower than my data predict because of differences in moisture content. I tested leaves that had already fallen from the tree and they were probably about 2-3% fuel moisture. Conversely, the leaf litter at Whatcom Creek was damp after a particularly wet spring (Fonda 2001). Also, because it was spring, the trees had newly formed young leaves instead of abundant litter. The only litter in June 1999 was partially decomposed litter from the previous fall. The combination of damp and decomposing litter could not sustain a fire as flammable as my data predict. If the Whatcom Creek fire had occurred in October, when leaves had fallen from the trees to constitute abundant, dry litter, they would have sustained a more intense fire. The excess of flammable litter could have also supported a moving fireline, which did not occur at Whatcom Creek because of the lack of dry litter. If dry, abundant litter had been available for the fire, the percent canopy scorch of trees would have been lower because leaf crowns would have fallen. Percent bark scorch, however, might have been higher. A high bark scorch percentage is predicted to have a low probability of survival for alder and cottonwood (Fonda 2001). Thus, had the Whatcom Creek fire occurred in October, it might have had an even more devastating effect on the trees in the riparian zone.

Literature Cited

Agee, J.K. 1993. Fire Ecology of Pacific Northwest Forests. Island Press, Covelo, CA.

Davis, K. 1959. Forest fire: control and use. McGraw Hill, Inc. New York, Toronto, London. 584 p.

Fonda, R.W. 2001. Postfire response of red alder, black cottonwood, and bigleaf maple to the Whatcom Creek fire, Bellingham, Washington. Northwest Science 75 (1): in press.

Fonda, R.W., L.A. Belanger, and L.L. Burley. 1998. Burning Characteristics of Western Conifer Needles. Department of Biology, Western Washington University, Bellingham, WA.

Fowells, H. A., compiler. 1965. Silvics of forest trees of the United States. Agricultural Handbook No. 271. Superintendent of Documents, Washington, DC.

Haeussler, S., and D. Coates. 1986. Autecological characteristics of selected species that compete with conifers in British Columbia: a literature review. Land Management Report No. 33. Ministry of Forests, Information Services Branch, Victoria, B.C., Canada.

Hansen, P. L., S.W. Chadde, and R.D. Pfister. 1988. Riparian dominance types of Montana. Misc. Publication. No. 49. University of Montana, School of Forestry, Montana Forest and Conservation Experiment Station, Missoula, MT.

Kennedy, H.E., Jr. 1985. Cottonwood: An American wood. FS-231. Washington, DC: U.S. Department of Agriculture, Forest Service.

Martin, R.E., D.A. Gordon, M.E. Gutierrez, D.S. Lee, D.M. Molina, R.A. Schroeder, D.B. Sapsis, S. L. Stephens, and M. Chambers. 1994. Assessing the flammability of domestic and wildland vegetation. *In* Proc.12th Internatl. Conf. Fire and Forest Meteorology. Soc. Amer. For., Bethesda, Maryland. p. 130-137.

Mutch, R.W. 1970. Wildland fires and ecosystems - a hypothesis. Ecology 51 (6): 1046-1051.

Schopmeyer, C. S. 1974. Alnus B. Ehrh. alder. In: Schopmeyer, C. S., technical coordinator. Seeds of woody plants in the United States. Agricultural Handbook No. 450. Superintendent of Documents, Washington, DC.

USDA Forest Service. 1998. Fire effects information system. Prescribed Fire and Fire effects Research Work Unit, Rocky Mountain Research Station, Missoula, MT. Available online at www.fs.fed.us/database/feis/.

Table 1. Species sampled and collection sites. Fire response classification is from Agee (1993) for pre-Whatcom Creek fire, and Fonda (2001) for post-WC fire. All species were collected in Bellingham, WA, 26 Oct - 20 Nov 1999.

Species	Classification for low/moderate intensity fires		Collection site
	pre-WC fire	post-WC fire	
Big leaf maple	Endurer	Endurer	Interurban Trail
Black cottonwood	Invader	Resister/Endurer	Lake Padden
Red alder	Invader	Endurer	Alabama Hill Trail

Table 2. Means of burning characteristics resulting from ten test burns for each species. Means connected by an underline are not significantly different.

MAXIMUM FLAME HEIGHT (cm)

Maple	Alder	Cottonwood
75.6	70.3	50.4

FLAME TIME (sec)

Cottonwood	Alder	Maple
80.9	45.8	41.0

EMBER TIME (sec)

Maple	Alder	Cottonwood
199.5	190.7	165.8

BURN TIME (sec)

Cottonwood	Maple	Alder
246.7	243.5	236.5

% COMBUSTED

Alder	Maple	Cottonwood
89.8	85.1	79.2

MEAN WEIGHT LOSS (mg/sec)

Maple	Alder	Cottonwood
67.7	66.5	57

Table 3. Means of burning characteristics for common Pacific Northwest tree species. Data for ponderosa pine, Douglas-fir, western redcedar, and western hemlock are from Fonda et al.(1998). Means connected by an underline are not significantly different.

FLAME HEIGHT (cm)

BLM	**RA**	PP	**CW**	WRC	DF	WH
75.6	**70.3**	69.3	**50.4**	42.4	26.2	24.6

FLAME TIME (sec)

WRC	DF	PP	**CW**	WH	**RA**	**BLM**
113.2	105.8	92.4	**80.9**	68.4	**45.8**	**41.0**

EMBER TIME (sec)

BLM	**RA**	**CW**	PP	WRC	WH	DF
199.5	**190.7**	**165.8**	149.7	130.7	43.6	21.8

BURN TIME (sec)

CW	WRC	**BLM**	PP	**RA**	DF	WH
246.7	243.9	**243.5**	242.1	**236.5**	127.6	112.1

% FUEL COMBUSTED

PP	**RA**	**BLM**	**CW**	WRC	DF	WH
91.1	**89.8**	**85.1**	**77.9**	45.7	26.6	18.8

RATE OF WEIGHT LOSS (mg/sec)

BLM	**RA**	**CW**	PP	DF	WRC	WH
67.8	**66.7**	**58.9**	58.2	31.6	28.5	26.8