Forest Ecology and Management 331 (2014) 188–195

Contents lists available at ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

Clearcutting and high severity wildfire have comparable effects on growth of direct-seeded interior Douglas-fir

Jason S. Barker [a,*], Suzanne W. Simard [a], Melanie D. Jones [b]

[a] Department of Forest and Conservation Sciences, University of British Columbia, Vancouver, BC V6T 1Z4, Canada
[b] Biology Department, University of British Columbia, Okanagan Campus, Kelowna, BC V1V 1V7, Canada

ARTICLE INFO

Article history:
Received 1 March 2014
Received in revised form 30 July 2014
Accepted 6 August 2014
Available online 7 September 2014

Keywords:
Wildfire
Harvesting
Regeneration
Direct-seeding
Douglas-fir

ABSTRACT

The degree to which harvesting can achieve comparable beneficial effects to wildfire on seedling establishment is a key factor in understanding regeneration dynamics in dry interior forest ecosystems. We compared the capacity of harvesting versus wildfire to support establishment of directly-seeded interior Douglas-fir over a three-year period in the interior Douglas-fir biogeoclimatic zone of British Columbia. The mixed-severity McLure Fire of August 2003 affected over 26,000 hectares in the central British Columbia, Canada. Within the fire-affected area, we assessed growth performance in five disturbance types: High Severity Burn, Low Severity Burn, Clearcut, Screefed Clearcut, and Undisturbed Forest. Seedlings in the High Severity Burn had the significantly greater shoot biomass and root biomass than those in the Low Severity Burn and Undisturbed Forest in the first year. Additionally, seedlings in the High Severity Burn had significantly higher foliar N and P content than those in both clearcut treatments in year one. Foliar nitrogen concentrations remained above critical deficiency levels (1.4%) in both clearcut treatments and the High Severity Burn treatment in all three years. Overall, seedling growth performance in Screefed Clearcut was the most comparable with High Severity Burn treatment, indicating the potential for harvesting with site preparation to produce comparable effects to wildfire on aspects of seedling establishment, particularly growth and nutrition.

1. Introduction

Wildfire has historically been a key disturbance creating the necessary conditions for natural tree regeneration in the dry interior forests of North America. Interest has been growing in incorporating natural disturbance emulation into management strategies to increase forest recovery after wildfire and other disturbances, in part by creating forest structures and environmental conditions to facilitate tree regeneration (McRae et al., 2001; Long, 2009). In forests dominated by interior Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco var glauca (Mayr)), the historic wildfire regime was mixed severity wildfire, which, when combined with both natural (insect outbreaks e.g.) and human-caused disturbances (logging e.g.), produce a heterogeneous forest landscape (Heyerdahl et al., 2006; Klenner et al., 2008). The degree that harvesting emulates wildfire depends on wildfire severity variation and the type of harvesting technique employed (Haeussler and Kneeshaw, 2003; Nitschke, 2005).

Given the mixed-severity regime in dry interior Douglas-fir forests, any attempt to improve regeneration success from seed must assess the growth potential of seedlings under a wide range of post-disturbance environments. A key comparison between harvesting and wildfire is their relative ability of disturbances to create favorable conditions for forest regeneration from seed. Both harvesting and wildfire can enhance interior Douglas-fir seedling growth by exposing mineral soil and reducing the abundance of competing vegetation (Greene et al., 1999; Flannigan et al., 2000). Wildfire appears to have greater potential to stimulate growth through increased nutrient availability than harvesting due to combustion of the forest floor (McRae et al., 2001). However, harvesting and site preparation can be applied to maximize forest floor disruption (e.g., through mechanical site preparation following logging) or remove competing vegetation, and thereby improve seedling growing conditions in temperate and boreal forests (Haeussler et al., 1999; Sutherland and Foreman, 2000).

The McLure Fire occurred in August of 2003 near Kamloops, British Columbia, and burned 26,420 hectares. This mixed-severity wildfire occurred within a forest area with active harvesting, and resulted in a mosaic of low, medium and high severity burns inter-mixed with clearcuts. This presented an opportunity to

* Corresponding author.
E-mail addresses: rhizo@mail.ubc.ca (J.S. Barker), suzanne.simard@ubc.ca (S.W. Simard), melanie.jones@ubc.ca (M.D. Jones).

http://dx.doi.org/10.1016/j.foreco.2014.08.004
0378-1127/

experimentally compare seed regeneration potential following different severities of wildfire and clearcutting disturbances on comparable sites. Our objective was to compare the ability of high and low severity wildfire vs clearcut harvesting to facilitate establishment of directly-seeded interior Douglas-fir by assessing seedling growth and foliar nutrient dynamics. First, we hypothesized that seedling growth would be higher under either type of stand-replacing disturbance than in control (undisturbed) or lightly burned forests, mainly as a result of increased resource availability (light, soil water and nutrients). Second, we hypothesized that nutrient availability to seedlings would increase with disturbance severity. We predicted that seedlings growing in the high severity burns and harvesting-with-screefing disturbance types would be associated with the highest seedling nutrient content. Taken together, we predicted that the clearcut harvesting-with-screefing and High Severity Burn disturbance types would have the best growth performance of seeded interior Douglas-fir.

2. Methods

2.1. Study area

The study was conducted in the vicinity of Barriere, British Columbia, Canada (51°00N, 120°00W). The sites were located between 400 m and 1400 m elevation within the Interior Douglas-Fir (IDF) biogeoclimatic zone, which is characterized by mean annual precipitation ranging from 300 to 850 mm (Lloyd et al., 1990). Soils at the study area were Brunisols and Luvisols of silty or sandy loam texture (Soil Classification Working Group, 1998).

Prior to disturbance, the forests were dominated by mature interior Douglas-fir with increasing amounts of subordinate lodgepole pine (*Pinus contorta* var. *latifolia* (Engelm.) Critchfield) at higher elevations. Common understory species included *Arctostaphlos uva-ursi* (L.) Spreng., *Linnaea borealis* L., *Lupinus arcticus* S. Watson, and *Calamagrostis rubescens* Buckl. (Lloyd et al., 1990).

2.2. Experimental design and treatments

In May 2004, 16 sites were located across a continuum of wildfire and harvesting disturbance severities, ranging from undisturbed forests to high severity burns and Screefed Clearcuts. The sites included five disturbance types (hereafter referred to as 'treatments': (1) High Severity Burn, (2) Low Severity Burn, (3) Screefed Clearcut, (4) Clearcut (without screefing) and (5) Undisturbed Forest. These treatments were examined on four replicate sites each that were located at least 1 km apart, except for the Clearcut and Screefed Clearcut treatments, which were located in the same replicate clearcuts. Measured site characteristics and climatic information are given in Table 1. Mean annual precipitation (MAP) and mean annual temperature (MAT) were estimated using the ClimateWNA, which combines climate data and modeling with site longitude and latitude data to produce historical climate variable estimates (Wang et al., 2012).

Burn severity was defined as the amount of organic material consumed by the fire (Johnstone and Chapin, 2006). In this study, we assessed burn severity based on fire effects on tree boles and the forest floor. Residual forest floor status was determined post hoc based on depth of forest floor charring and exposure of mineral soil. At the High Severity Burn sites, the forest floor was completely consumed and the mineral soil exposed (residual depth of forest floor 0.7, se 0.2 cm). Only charred boles of fire-killed trees remained of the canopy and understory trees, which were removed prior to study initiation using a mechanical harvester. At the Low Severity Burn sites, at least 95% of the canopy survived (based on number of tree stems) the fire but 100% of the understory was killed (residual depth of forest floor 1.8, se 0.5 cm). We required that the High Severity Burn and Low Severity Burn conditions occurred uniformly over an area at least 50 m × 50 m to qualify as a replicate site.

The Undisturbed Forest and clearcut sites were located either within the overall perimeter or at the immediate periphery (within 4 km) of the McLure Fire. The Undisturbed Forests were dominated by mature Douglas-fir trees that were estimated to be 100–200 years old. Forest floor depth averaged 4.9, se 0.6 cm. The clearcut sites were harvested in the winter of 2003–2004 and were cleared of canopy cover over an area of at least 1.5 ha. In May 2004, two circular plots (see paragraph below) were located within each clearcut and randomly assigned the Clearcut or Screefed Clearcut treatment. In the Screefed Clearcut treatment, all vegetation and forest floor was removed (screefed) down to the mineral soil using shovels and rakes (depth of forest floor 0 cm). In the Clearcut treatment, the forest floor was left intact leaving an average depth of forest floor 3.8 (se 0.4 cm).

Treatment effects were assessed within a single 15-m circular plot at each replicate site. Within each plot area, five seed beds (120 cm × 140 cm) were located. Wooden stakes were driven into the ground to mark the four corners and center of each seedbed. Seeds of interior Douglas-fir (seedlot 48523, originating within 50 km of study sites, Tree Seed Center, Ministry of Forests and Range, Surrey, B.C., Canada) were stratified at 4 °C for 3 weeks and sown into the seedbeds during the first two weeks of May, 2004. At each seedbed, seven to eight narrow rows (<1 cm wide) were dug through the forest floor (where it remained) to expose bare mineral soil for sowing. The mineral soil was only disturbed 1–2 mm by the digging. The seedbeds were sown with 1000 seeds per replicate site, or 200 seeds per individual seedbed. Seeds were covered by a thin layer of mineral soil and organic matter (if present). All vegetation establishing within and adjacent to the seedbeds was clipped at the root collar and removed from the plots. There was little vegetation, except for some pinegrass (*Calamagrostis rubescens* Buckl. (Poaceae)) at the clearcut sites and fireweed (*Epilobium angustifolium* L.), at the High Severity Burn sites. Natural Douglas-fir regeneration was absent from the clearcut, Undisturbed Forest and High Severity Burn sites, but some occurred near the seedbeds in the Low Severity Burn sites, and were removed. The original goal of the study was to compare seedling growth and foliar nutrient status in all 5 treatments for three years after germination; however, poor survival in the Low Severity Burn and Undisturbed Forest treatments after the first growing season prevented a growth comparison with the stand-replacing treatments in 2005–2006. Additionally, one High Severity Burn site

Table 1
Range of site properties in each disturbance treatment. MAP = Mean Annual Precipitation. MAT = Mean Annual Temperature.

Treatment	Elevation range (m)	MAP (mm)	MAT (°C)	Slope range (%)	Aspect (# of sites)
High Severity Burn (HSB)	806–1179	449–514	3.6–5.3	0–6	NW (3), NE (1)
Low Severity Burn (LSB)	700–1176	427–508	4.3–5.6	2–24	NE (2), SE (1), SW (2)
Screefed Clearcut (SCC)	1000–1268	433–603	3.3–4.4	8–20	NW (2), NE (1) SW (1)
Clearcut (CC)	1000–1268	433–603	3.3–4.4	8–20	NW (2), NE (1) SW (1)
Undisturbed Forest (UF)	843–1176	423–487	3.9–5.2	0–11	NW (3), NW (1)