Forest Ecology and Management 401 (2017) 286–294

Contents lists available at ScienceDirect

Forest Ecology and Management

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

An evaluation of seven methods for controlling mountain laurel thickets in the mixed-oak forests of the central Appalachian Mountains, USA

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ARTICLE INFO

Article history:
Received 5 April 2017
Received in revised form 14 June 2017
Accepted 17 June 2017

ABSTRACT

In the Appalachian Mountains of eastern North America, mountain laurel (*Kalmia latifolia*) thickets in mixed-oak (*Quercus* spp.) stands can lead to hazardous fuel situations, forest regeneration problems, and possible forest health concerns. Therefore, land managers need techniques to control mountain laurel thickets and limit their deleterious effects. From 2001 to 2009, I compared the effectiveness of seven understory management techniques (two chemical, two fire, two mechanical, and an untreated control) for reducing mountain laurel thickets. All of the methods except the control decreased mountain laurel coverage for at least 2 years and facilitated establishment of oak seedlings and other hardwood reproduction. However by the fifth year, the mountain laurel thickets had nearly redeveloped and the reproduction of several other hardwood species were outgrowing the oak seedlings. Additionally, all of the methods had operational issues that limited their effectiveness. Research into broadcast herbicides that kill the mountain laurel long-term and prevent redevelopment is needed as none of the techniques tested in this study provided effective control beyond a few years.

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1. Introduction

Throughout forests of the northern hemisphere, some species of heath shrubs (Family: Ericaceae) can form persistent understories (Royo and Carson, 2006). In the Appalachian Mountains of eastern North America, mountain laurel (*Kalmia latifolia*) is one such species (Brose, 2016; Chastain and Townsend, 2008; Monk et al., 1985). The shrub grows up to 4 m tall and broad, is evergreen and shade tolerant, and occurs primarily on dry and intermediate sites (Chapman, 1950; Kurmes, 1961). Mountain laurel spreads via layering of the lowermost branches as well as dissemination of thousands of minute seeds (Chapman, 1950; Kurmes, 1961). In the absence of recurring fire, these silvical characteristics lead to dense thickets that can consist of thousands of stems/hectare and cover several hectares (Brose, 2016; Chapman, 1950; Monk et al., 1985).

Mountain laurel thickets can lead to several forest management problems. Because they occur on dry and intermediate sites, mountain laurel thickets often dominate the understories of the ecologically and economically important mixed-oak (*Quercus* spp.) forests. Their evergreen leaves cast perpetual shade and the resulting light level on the forest floor is usually less than 5 percent of full sunlight (Beckage et al., 2000; Clinton et al., 1994; Monk et al., 1985), a level too low for the long-term survival and development of oak seedlings (Brose, 2011a; Miller et al., 2004). Consequently, oak seedlings are usually scarce, small, and suppressed in mountain laurel thickets, making regeneration of this valuable forest type an arduous protracted process. Also, mountain laurel thickets are highly flammable; their leaves have a waxy cuticle and they contain volatile phenolic compounds. Waldrop and Brose (1999) documented flame lengths exceeding 7 m when mountain laurel thickets burned during a spring prescribed fire in northern Georgia. Such fire behavior often results in the damage and/or death of the overstory trees (Waldrop and Brose, 1999; Waldrop et al., 2008) and poses a threat to human life and property as demonstrated by the recent fires in eastern Tennessee (Gabbert, 2016; Wilent, 2017). Finally, mountain laurel is susceptible to *Phytophthora ramorum*, the fungus that causes sudden oak death in California and Oregon, making the shrub a likely host if the disease becomes established in the eastern United States (Tooley and Kyde, 2007; Tooley et al., 2004).

Research on controlling mountain laurel thickets has been sporadic for several decades. The control techniques can be placed into three categories (herbicides, mechanical techniques, and prescribed fire) and these have been tested on a limited basis. Regarding herbicides, researchers have tested both chemicals and their application methods. Sluder (1958) compared two herbicides commonly used at that time, 2,4,5-Trichlorophenoxyactic acid solution (2,4,5-T) and ammonium sulfate (Ammate), and two application methods, basal bark and cut stump, as controls for mountain laurel

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http://dx.doi.org/10.1016/j.foreco.2017.06.041
0378-1127/Published by Elsevier B.V.

in western North Carolina. The 2,4,5-T applied via a diesel oil solution to the lower stem of the mountain laurel resulted in 70 percent of the shrubs completely killed with virtually no basal sprouting. Similarly, when the 2,4,5-T was applied via the cut stump technique, only 4 percent of the stumps produced sprouts. Conversely, applying Ammate crystals to mountain laurel stumps did not control the shrub as the stumps subsequently averaged 46 sprouts. In Virginia, Picloram pellets (4-Amino-3,5,6trichloro-2 -pyridinecarboxylic acid) applied during the summer at 4.5 or 6.0 kg/ha killed 77 –97 percent of the mountain laurel stems by the following year (Neary et al., 1984).

Mechanical control involves crushing, cutting, or otherwise physically damaging the thickets with equipment. This may be done in conjunction with a logging operation or as site preparation for planting seedlings. In North Carolina, Wahlenberg and Doolittle (1950) tested four mechanical means of removing mountain laurel thickets: cutting by hand, cutting and root grubbing by hand, and clearing lanes and spots with a small bulldozer. These techniques were followed by planting of eastern white pine (*Pinus strobus*) seedlings. After 14 years, the mountain laurel thickets had re-established themselves in the cutting and cutting/grubbing treatments and more than 50 percent of the pine seedlings had failed to grow taller than the shrubs. Conversely, clearing the mountain laurel with the small bulldozer resulted in the thickets not reforming as quickly and more than 50 percent of the pine seedlings growing taller than the shrubs in 14 years. More recently, Waldrop et al. (2016) reported the results of chainsaw felling of mountain laurel from the North Carolina replicate of the nationwide Fire and Fire Surrogates (F/FS) Project. They found chainsaw felling initially reduced mountain laurel density from 1433 to 447 stems/ha while cover dropped from 77 to 8 percent. These reductions were temporary; within 5 years mountain laurel density and cover had rebounded to 1210 stems/ha and 22 percent, respectively.

Historically, recurring fire at a frequency of approximately once a decade was a likely factor limiting the density and size of mountain laurel thickets (Brose et al., 2014; Lafon et al., 2017; Marschall et al., 2016) so researchers have investigated prescribed fire as a control agent. In North Carolina, Hooper (1969) found that a dormant-season burn killed or heavily damaged more than 80 percent of the mountain laurel stems. Nearly all these shrubs sprouted from their bases, but regrowth was slow, less than 15 cm/year, so planted pines were likely to pass the mountain laurel before the thicket reformed. Also in North Carolina, Hagan et al. (2015) reported similar sprouting following a spring wildfire, but a second spring wildfire 7 years later reduced mountain laurel stem densities by more than 2000 stems/ha. In the northeastern United States, Ducey et al. (1996) and Ward (2015) noted that mountain laurel was the most prolific sprouter following prescribed fires of varying seasonality and intensity. In the aforementioned F/FS Project, Waldrop et al. (2016) found that three prescribed dormant-season fires conducted over a decade actually increased mountain laurel stem density although the shrub's cover was decreased by approximately 50 percent.

Fire, herbicides, and mechanical controls have also been tested in combinations to a limited degree. Romancier (1971) used fire to initially top-kill mountain laurel followed 2 years later with various herbicides on the new sprouts. He found 2,4,5-T applied as a basal spray and two foliar sprays also containing 2,4,5-T to provide almost 100 percent control of the shrub. Waldrop et al. (2016) combined chainsaw felling (two applications) and dormant-season prescribed fire (three burns) over a 12-year period in western North Carolina. While each treatment initially reduced mountain laurel density, by the end of the study shrub density was 6.5 times more abundant than before the project began (1596 stems/ha versus 10,169 stems/ha).

Aside from the F/FS Project (Waldrop et al., 2016), a limitation in much of this research is that they were case studies (one replication) of a singular treatment (fire or herbicide or mechanical) compared to an untreated control. Consequently, foresters are left unsure as to how the treatment methods compare to each other. Additionally, much of this research was done decades ago and is no longer relevant (2,4,5-T was discontinued in 1985). To address these limitations, I designed and carried out an 8-year study at three sites across Pennsylvania to compare the effectiveness of seven common methods (two fire, two herbicide, two mechanical, and an untreated control) for regenerating mixed-oak forests with interfering mountain laurel thickets. My hypothesis was that the treatments would form a continuum of effectiveness (most to least): herbicides $\gg$ fire = mechanical $\gg$ control. Understanding how these various treatments compare to one another will help foresters trying to manage mixed-oak forests on sites where mountain laurel thickets are problematic.

2. Methods

2.1. Study sites

This study was conducted from 2001 to 2009 in three upland oak stands located across Pennsylvania (Fig. 1). The westernmost site (4°19′03″N, 79°02′21″W) was on Clear Creek State Forest (CCSF) while the easternmost site (41°18′27″N, 75°05′50″W) was on Delaware State Forest (DESF). The third site was in central Pennsylvania (40°42′59″N, 77°54′03″W) on the Rothrock State Forest (RRSF). Despite being 150–400 km from each other, the three study stands shared a number of characteristics. Each stand was 15- to 20-ha, situated on the upper slopes or summits of hills, had a stony loam soil, and an oak site $index_{50}$ of 16–20 m (Braker, 1981; Taylor, 1969; Zarichansky, 1964). In the upper canopy, chestnut oak (*Quercus montana*) and northern red oak (*Q. rubra*) were the most abundant oak species, but black oak (*Q. velutina*), scarlet oak (*Q. coccinea*), white oak (*Q. alba*), pitch pine (*Pinus rigida*), and white pine were also present. Associated midstory tree species included black birch (*Betula lenta*), blackgum (*Nyssa sylvatica*), red maple (*Acer rubrum*), sassafras (*Sassafras albidum*), and serviceberry (*Amelanchier arborea*). Canopy cover was not ubiquitous due to past canopy disturbances, but I visually estimated overstory stocking to be more than 70 percent. Mountain laurel dominated the understory plant community with its abundance ranging from individual shrubs to thickets covering a few hectares. Also present were other shrub species such as bear oak (*Q. ilicifolia*), blueberry (*Vaccinium* spp.), huckleberry (*Gaylussacia* spp.), and sweet fern (*Comptonia peregrina*). Herbaceous plant diversity was quite limited; it consisted of small areas of hay-scented fern (*Dennstaedtia punctilobula*) and scattered specimens of beetleweed (*Galax aphylla*), Virginia tephrosia (*Tephrosia virginiana*), trailing arbutus (*Epigaea repens*), and wintergreen (*Gautheria procumbens*). Similarly, hardwood reproduction was infrequent and consisted of small seedlings of the same species as the overstory and midstory trees.

Because these sites were 150–400 km apart, they differed in a number of characteristics. The CCSF site was in the Allegheny Plateau region while the DESF and RRSF sites were in the Pocono Plateau and Ridge/Valley regions, respectively (Schultz, 1999). Their weather varied with CCSF being the coolest and wettest (−9.4 to 25.1 C, 1080 mm rainfall), RRSF being the warmest and driest (−4.4 to 28.0 C, 1030 mm rainfall), and DESF was intermediate (−6.0 to 26.0 C, 1050 mm rainfall) (Braker, 1981; Taylor, 1969; Zarichansky, 1964). The RRSF site was on a north aspect while the other two sites had southeastern aspects. The CCSF site was the highest, approximately 575 m, while DESF and RRSF were