THE INFLUENCE OF SOIL SCARIFICATION ON OAK REPRODUCTION: REVIEW AND MANAGEMENT CONSIDERATIONS

John M. Lhotka, James J. Zaczek, and Russell T. Graham[1]

Abstract—Changes in historic disturbance regimes and the resulting changes in forest composition and structure have contributed to oak (*Quercus* spp.) regeneration difficulties across much of its geographic range. One important component of oak regeneration is the establishment and development of advance oak reproduction. Another is reducing competing vegetation to enhance the development of oak reproduction. Past and ongoing research in the use of soil scarification to enhance establishment and competitive position of oak reproduction from seed is summarized in this paper. Within each study presented, initial establishment of oak reproduction was significantly greater in scarified areas compared to the controls. From these studies, a series of management recommendations have been developed and will be presented to provide researchers and land managers with information on applicability of soil scarification treatments to enhance initial establishment oak reproduction.

INTRODUCTION

Alteration of disturbance regimes in the central and eastern United States has developed understory conditions that have led to the dominance of shade-tolerant species in the understory of many oak (*Quercus* spp.) stands (Lorimer 1984, Abrams 1992, Abrams and Nowacki 1992). With the change in the understory environment following this shift in forest structure, the establishment and development of oak reproduction has diminished (Abrams 1992, Lorimer and others 1994, Brose and others 1999). Other factors such as vertebrate predation, sporadic acorn production, weevil (*Curculio* spp) infestations, and microsite variability may also play a role in limiting the establishment of oak reproduction (Gribko and others 2002). The lack of periodic disturbance compounded with inherent biotic and abiotic factors influencing oak establishment has made the regeneration of many oak stands difficult.

Acorn survival and germination is a necessary precursor for the establishment of oak reproduction. However, few acorns ever germinate into seedlings due to factors such as losses from predation and exposure of acorns to unfavorable environmental conditions (Crow 1988, Ostfeld and others 1996). It has been suggested that soil scarification, in the presence of abundant acorns, may be useful to disrupt competing vegetation and enhancing the initial development of oak reproduction (Lhotka and Zaczek 2003a, 2003b; Zaczek 2002). Specifically, scarification promotes favorable germination conditions for acorns, provides protection from predation, and plays a role in controlling competing vegetation (Crow 1988). The results of four soil scarification studies and a discussion of the implications of these studies in using scarification to enhance the density and development of oak reproduction is outlined in this paper.

PAST AND ONGOING STUDIES

Two recent studies conducted in southern Illinois suggest that, in the presence of abundant acorns, soil scarification can help increase the initial density of oak seedlings (Lhotka and Zaczek 2003a, 2003b). One study was conducted in an upland forest dominated by white oak (*Quercus alba* L.) and black oak (*Quercus velutina* Lam.). The stand contained a dense midstory of well-established sugar maple (*Acer saccharum* Marsh.) saplings and suppressed trees and little advance oak reproduction. In October 1999, a 78-hp crawler tractor with a 2.44-m-wide six-tooth brush rake was used to scarify the soil. One year after treatment, scarified areas had greater oak seedling densities (5,164 ha^{-1}, 20 percent of total seedlings) when compared to undisturbed areas (1,273 ha^{-1}, 9 percent of total seedlings). Scarification also reduced midstory density by removing 31 percent of the sugar maple stems within the scarified areas (Lhotka and Zaczek 2003a).

A second study conducted in southern Illinois during the same period was established in a bottomland forest composed primarily of cherrybark oak (*Quercus pagoda* Raf.) and post oak (*Quercus stellata* Wangenh.) (Lhotka and Zaczek 2003b). The understory had sparse tree regeneration and was dominated by poison ivy (*Toxicodendron radicans* L.). A 42-hp wheeled tractor pulling a 2.44-m wide field disk was used to conduct the soil scarification. One year after scarification, scarified plots had greater oak seedling densities (7,243 ha^{-1}, 42 percent of total seedlings) than did control plots (453 ha^{-1}, 9 percent of total). At the same time, poison ivy cover in the scarified plots (7 percent) was reduced compared to controls (35 percent). First year results, from the upland and bottomland studies conducted in Illinois, suggest that soil scarification has the potential to increase initial establishment of oak and may have the ability to control competing vegetation.

An early soil scarification study conducted within a northern red oak (*Quercus rubra* L.) stand using disk scarification also showed increased establishment of oak following soil scarification (Scholz 1959). However, seven years after treatment the initial advantages of disk scarification were

[1] Forester, USDA Forest Service, Rocky Mountain Research Station, Moscow Forestry Sciences Laboratory, Moscow, ID 83843; Assistant Professor, Department of Forestry, Southern Illinois University, Carbondale, IL 62901; and Research Forester, USDA Forest Service, Rocky Mountain Research Station, Moscow Forestry Sciences Laboratory, Moscow, ID 83843, respectively.

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no longer present. From the study, it was apparent that the stand conditions were not conducive to oak seedling development, for the average seedling height was only 19 cm after seven years. This trend suggests that without the appropriate growing conditions for oak in place at the time of treatment such as adequate light levels, protection from deer browse, or control of competing vegetation the early advantages gained by scarification may diminish over time.

A fourth study reviewed in this paper was conducted within a poorly regenerating upland mixed-oak fenced shelterwood in central Pennsylvania. The stand's understory was dominated by red maple seedlings and had relatively few small oaks. A soil scarification treatment was applied in 1993 within the shelterwood using a small crawler tractor and 1.8-m-wide brush rake. Soil scarification conducted within shelterwood and in the presence of abundant viable acorns increases the initial density and competitive position of oak and that the advantage is apparent through year five (Zaczek and others 1997, Zaczek 2002, Zaczek and Lhotka, in press). One year after scarification, 32,618 oak seedlings ha^{-1} (78 percent of total seedlings) were found in the scarified plots, while only 9,435 oak seedlings ha^{-1} were located in the control. The overwood and fence were removed at year three. Five years after treatment, a greater density of oaks (39,432 ha^{-1}) still remained in scarified plots when compared to controls (12,971 ha^{-1}). Additionally, within the disturbed areas, greater oak densities were present in the larger size classes compared to other species including red maple. The competing red maple reproduction was significantly reduced in density and height in response to scarification. Unlike the Scholz (1959) study, the Pennsylvania upland study was conducted in a stand with an understory environment more conducive to the development of oak seedlings. This contrast in understory environments between the two studies may explain the differences in understory dynamics seen over time.

MANAGEMENT IMPLICATIONS

While soil scarification can increase the initial establishment of desired oak species, operational and biological influences may control the success of an operation. First, abundant viable acorns must be present at the time of treatment, for without the necessary seed, a soil scarification operation will only serve to disrupt the existing vegetation and fail to develop new oak germinants. Timing of scarification operation is also crucial. It is recommended that areas be scarified in the autumn of an abundant mast year following acorn drop, but before leaf fall. This is important because it is suggested that the litter accumulation after leaf fall may provide additional protection against acorn predation (Bundy and others 1991).

Extremely wet or dry conditions at the time of treatment may also influence the success of the operation. Extremely dry conditions may cause acorns to desiccate and fail to germinate (Olson and Boyce 1971) and the depth of penetration by a disk in dry soils is limited. On the other hand, scarification may compact or displace soils and may bury acorns too deeply, resulting in decreased seedling emergence.

A wide array of power sources and implements have been used for scarification in forest operations. Selection of an appropriate system must balance traction, soil scarification, and maneuverability. An important factor influencing a scarification operation is the presence of a dense midstory and understory. Density is important because it may hamper machinery maneuverability. The small-wheeled tractor with disk, small crawler tractor with brushrake or Salmon blade, and a modified drag-chain scarifier pulled by a small crawler tractor are three methods that may be used for scarification in partial harvests (Karsky 1993, Zaczek and others 1997, Lhotka and Zaczek 2003b). These systems have the size and maneuverability to operate in a partially harvested stand without damaging residual trees, but still have sufficient power to complete the operation (Karsky 1993). The disking and drag-chain method may be preferred in open stands, but the mobility of the equipment may be severely limited in dense stands or those containing large amounts of slash. Therefore, it may be necessary to thin and/or remove slash prior to implementing the disk or drag-chain method. In contrast, the bulldozer/brushrake method has the ability to operate in dense and recently harvested stands, while still providing scarification benefits (Zacaek and others 1997, Zaczek 2002). Damage to residual crop trees is possible so careful operation of equipment is necessary. For these reasons, it is important to consider stand conditions prior to planning a scarification operation.

Precision application of disturbance is another benefit that scarification can provide. In contrast, other oak regeneration enhancement treatments such as prescribed fire may be difficult or impractical to apply in small or irregular-shaped patches and exclusion from sensitive areas may be problematic. With the ability to pinpoint treated areas, a manager could scarify poorly regenerating areas, while avoiding streamside buffer zones, temporal ponds, or other unique habitats.

Soil scarification may increase initial establishment, but this silvicultural treatment alone may not create appropriate conditions for the development of large, vigorous seedlings. Without the necessary environmental conditions in place, continued growth and survival of scarification produced seedlings may be limited. Many factors can influence further development of understory reproduction. A well-developed midstory and associated low light levels will greatly hinder the development of oak seedlings (Lorimer and others 1994). The intolerant to midtolerant oak species are especially harmed and cannot survive over a long period in these low light levels (Crow 1988, Nowacki and Abrams 1992). Competing vegetation, deer browse, insects, disease, and other environmental variables may also add to seedling mortality (Crow 1988, Lorimer 1993, Oak 1993). It has been suggested that a manipulation of the midstory or overstory may help alleviate some of the problems created by low light levels (Loftis 1983, Janzen and Hodges 1985, Loftis 1990, Lockhart and others 2000). Without release, seedling survival will be limited. This resulting mortality may leave the stand in a condition similar to that present prior to the scarification treatment.

Given the presence of abundant viable acorns, scarification has been shown to increase oak seedling density. It is also suggested that scarification may control competing midstory and understory vegetation (Lhotka and Zaczek 2003a, Zaczek and Lhotka, in press). However, scarification may also promote sprout development and therefore the response of competing vegetation should be evaluated prior to scarification. Finally, we stress that silvicultural procedures such as an overstory thinning should be applied prior to or in concurrence with scarification to help enhance the survival, growth, and development of newly established oak seedlings.

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