THE USE OF SOIL SCARIFICATION TO ENHANCE OAK REGENERATION IN A MIXED-OAK BOTTOMLAND FOREST OF SOUTHERN ILLINOIS

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Abstract-The purpose of the study was to investigate whether soil scarification following seed fall can be used to increase the density of oak regeneration in a mixed-oak stand. The study area was a 4.5-hectare stand dominated by cherrybark oak (Quercus pagoda Ell.). The understory had a high percent cover of poison ivy *(Toxicodendron radicans* (L.) Kuntze) and essentially lacked oak advance regeneration. In November 1999, the scarification treatment was accomplished using a tractor with a pull-behind field disk. One growing season after scarification, the number of oak seedlings was significantly higher in scarified plots (7,243/ha) than in the control plots (453/ha). Percent cover of poison ivy decreased from 36 percent to12 percent in the scarified plots. These results suggest that, in the presence of abundant acorns, scarification increased the likelihood of oak germination in a stand that lacked advanced oak regeneration prior to the treatment. Finally, because scarification increased the density of oak seedlings, it will increase the likelihood that mixed-oak stands can be successfully regenerated after a canopy disturbance.

INTRODUCTION

It is well documented that in order to regenerate oak stands a sufficient amount of competitive advance regeneration must be present before a harvest (Crow 1988, Johnson and others 1989, Meadows and Stanturf 1997, Zaczek and others 1997, Larsen and Johnson 1998). Understory treatments such as mechanical removal and chemical control of competition have been proposed to increase oak establishment and growth in bottomland oak forests (Crow 1988, Johnson and others 1989, Loftis 1990, Nowacki and others 1990, Bundy and others 1991, Nowacki and Abrams 1992, Zaczek and others 1997). Soil scarification is one other treatment that has been proposed (Scholz 1959, Bundy and others 1984, Crow 1988, Johnson and others 1989, Barry and Nix 1992, Zaczek and others 1997). Soil scarification may help to provide favorable germination conditions for acorns, protection from predators, and control competition (Crow 1988, Zaczek and others 1997) and therefore increase the likelihood of germination and development into a vigorous seedling.

Soil scarification may increase acorn germination and survival by incorporating the acorns into the soil (Zaczek and others 1997, Lhotka 2001). Acorn germination conditions have been shown to be more favorable below the soil surface than on the soil surface (Griffen 1971, Janzen 1971). In addition, acorns buried below the surface have been shown to be less susceptible to animal damage (Auchmoody and others 1994, Nilsson and others 1996). It is important to provide this protection because of high acorn predation rates (Auchmoody and others 1994, Steiner 1995). Because scarification helps to incorporate acorns below the surface, it may increase the chances that an acorn will germinate and develop into a vigorous seedling. Scarification may also help control competing vegetation. With a decrease in competing vegetation, newly established seedlings may gain a better competitive position and have an increased chance for successful development.

The purpose of the study was to investigate whether soil scarification, in the presence of abundant acorns, can be used to enhance oak regeneration in a mixed-oak bottomland forest. This paper reports the germination and survival of oak regeneration one year after soil scarification.

METHODOLOGY

The study was conducted in a 4.5-hectare mixed oak-hickory bottomland forest stand located in Saline County, Illinois. The overstory was composed of cherrybark oak *(Quercus pagoda* Ell.), shagbark hickory (*Carya ovata* [Mill.] K. Koch), mockernut hickory (*Carya tomentosa* [Poir.] Nutt.), and post oak (Quercus *stellata* Wang.). The understory was dominated by a thick blanket of poison ivy *(Toxicodendron radicans* [L.] Kuntze) and essentially lacked advanced oak reproduction.

Prior to scarification, eight linear transects to receive scarification were laid out within the stand. A total of fifty 1.77 m^2 plots were located along the center of the transects to measure existing vegetation. An additional fifty 1 m quadrats were located along the transects to measure the number of acorns and hickory nuts present prior to treatment. Unscarified control plots were paired with each scarified plot and were located 3.8 m from the center of the scarified transects (figure 1). The plots were allocated proportionally according to the length of the transect. All trees < 1.5 m in height were measured to the nearest 0.1 m. Percent cover of vine and shrub species were also

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Table I-The density (number per ha) of viable seeds by treatment and species group

Species	Density of Viable Seeds	
	Control	Scarified
All Oaks[a]	47,466	56,399
Hickory[b]	932	1,598

[a] All Oaks include: *Quercus bicolor* Willd., *Quercus michauxii* Nutt., *Quercus macrocarpa* Michx., *Quercus pagoda* Eli., *Quercus stellata* Wang.
[b] Hickory includes: *Carya ovata* (Mill.) K. Koch., *Carya tomentosa* (Poir.) Nutt.

measured at that time. The acorn crop was measured by using 1 m^2 plots placed directly adjacent to the center of each vegetation plot. At each acorn plot, acorns were tallied by species and a sample was collected to test for germination success.

Scarification was completed on November 5, 1999 using an International 464 tractor with an international 122 disk. The disk was approximately 2.44-meters wide. This International 122 is a standard-type field implement with rolling metal disks that help to penetrate the soil and mix the upper soil layer. Because the ground was very dry, the area was scarified by making three passes across the transects with the disk. The paired control plots were left undisturbed.

The overstory inventory was conducted in May 2000 using twenty 7.98 m radius plots. All trees >1.5 m in height and <9 cm DBH were measured. A relative importance value was then calculated for each species (Cottam and Curtis 1956). At each overstory plot,a 25 m^2 plot was used to measure all trees <1.5 m in height and less than 9 cm at DBH.

Table P-Tree Seedlings densities (stems per ha) by species, inventory date, and treatment

Species	Pretreatment Stems per ha		October 2000 Stems per ha	
	Control	Scarified	Control	Scarified
All Oaks[a]	566	453	453	7,243*
Acceptable Hardwoods[b]	3,778	5,206	4,640	10,072'

*indicates significant difference between treatments at alpha = 0.05
[a] All Oaks include: *Quercus pagoda* Ell., *Quercus stellata* Wang.
[b] Acceptable Hardwoods include: *Carya ovata* (Mill.) K. Koch., *Carya tomentosa* (Poir.) Nutt., *Comus racemosa* Lam., *Diospyros virginiana* L., *Fraxinus pennsylvanica* Marsh., *Ulmus americana* L.)(American elm), red elm, (*Liquidambar styraciflua* L., *Nyssa sylvatica* Marsh.) *Prunus serotina* Ehrh., Sassafras albidum (Nutt.) *Nees, Ulmus alata* Mic

In October 2000, understory vegetation was measured along transects using fifty randomly located 1.77 m^2 radius paired plots to reflect first year survival. The number of stems was summarized into four species groups (All Oaks, Acceptable Hardwoods, Total Tree Seedlings, and Poison Ivy). The pretreatment acorn number and regeneration density by species for each inventory were analyzed by using one-way analysis of variance (ANOVA) at an alpha = 0.05 to test for differences between the control and scarified treatments.

RESULTS

The stand had a mixed bottomland oak-hickory composition with a basal area of 28 m^2/ ha and a density of 365 stems / ha. The dominant overstory species were cherrybark oak, shagbark hickory, mockernut hickory, and post oak. Other species did not exceed 2.0 in importance value. The stand had a very sparse midstory canopy

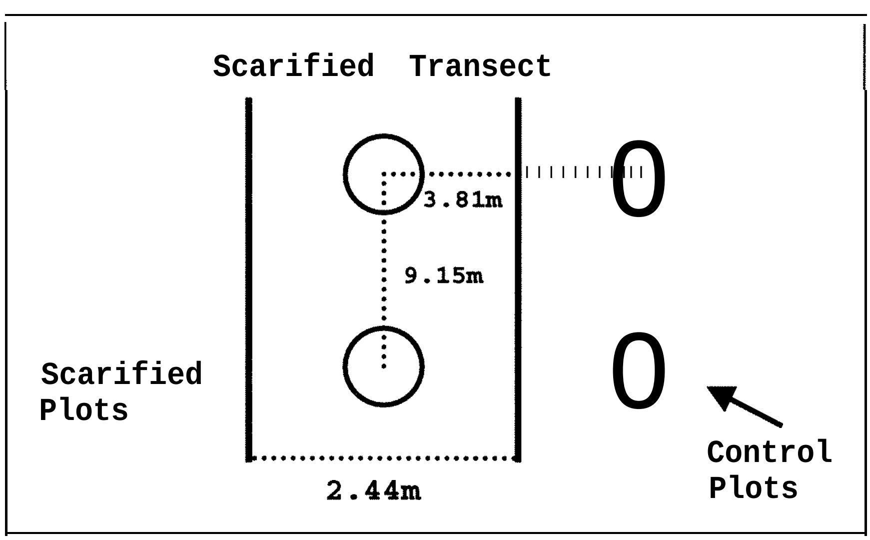

Figure I-Paired plot sampling design for understory vegetation inventory stratum and was comprised of only 280 total stems/ha. Of these stems, 57 percent were green ash *(Fraxinus pennsylvanica* Marsh.) and 21 percent were hickories (*Carya spp.*).

The prescarification vegetation inventories and acorn counts showed no significant difference between the control and scarified plots. The number of acorns ($F = 0.50$, $p = 0.4792$, $df = 1,99$) (table 1) and the number of total seedlings ($F = 0.25$, $p = 0.6167$, $df = 1,99$) were not significantly different between the control and scarified plots (table 2). The number of acceptable hardwoods in the scarified plots was also not significantly different ($F = 0.36$, $p = 0.5506$, $df = 1,99$) than the number in the control. The height distribution prior to treatment was spread across all height classes, but an increased frequency occurred in the classes shorter than 85cm. Also in the understory, the poison ivy cover was also not significantly different ($F = 0.10$, $p = 0.7570$, $df = 1,99$) between the control and scarified plots.

One year after treatment, the scarified plots had a higher seedling density than the control (table 2). The oaks, especially, had higher densities in the scarified plots. This large increase in oak in the scarified plots was related to increased germination rates. The germination percentage of viable acorns found in the scarified plots was 9 percent, while in the control plots the percent germination was near zero. As a result of the new germinants, the number of oaks was significantly higher ($F = 14.96$, $p = 0.0002$, $df = 1,99$) in the scarified plots than in the control plots. In addition, the number of acceptable hardwood species was significantly higher in the scarified plots. One year after treatment, the oaks composed 42 percent of all seedlings in the scarified plots, but only made up 9 percent of all seedling in the control. Unlike tree seedling density, the percent cover of poison ivy was significantly lower ($F = 26.43$, $p = 0.0001$, $df = 1.99$) in the scarified plots (12 percent) than in the control plots (36 percent).

Scarified plots also had fewer large seedlings than the control plots. In the control plots, 1,697 stems / ha occupied the height classes > 44 cm and 2,490 stems / ha were present in the lower two height classes (O-24 cm, 25-44 cm) and these stems were mostly green ash. Oaks only accounted for 14 percent of the total stems in the lower two height classes and only 7 percent of the total stems > 44 cm in height in the control plots. Unlike the control plots, the scarified plots only had 339 stems/ha (2 percent of total) present in the height classes greater than 44 cm. Ninety-eight percent of the seedlings in the scarified plots were less than 44 cm in height and 86 percent of the total stems are less than 25 cm in height. In the scarified plots, oaks accounted for 48 percent of all species in the O-24 cm height class and no oaks are greater than 24 cm in height.

DISCUSSION

The scarification apparently enhanced acorn germination even under severe predation pressure. Of the potentially viable acorns remaining at the time of scarification, the germination percentage in the scarified plots was 9 percent, while the control plots had no new germinants. Although the germination percentage in the scarified plots was somewhat low, even a small increase in germination percentage resulted in greatly increased numbers of oak recruits and the overall pool of advanced regeneration.

Past soil scarification research had similar early results to this study. A project conducted by Scholz (1959) used a disking method to improve the initial establishment of northern red oak. After the first year, the study showed an increase in northern red oak densities in the disk plots. In addition, a study conducted by Zaczek and others in 1997 found that higher proportions of acorns germinated in the scarified plots (28 percent) than in the control plots (2 percent). In addition, a significantly greater number of northern red oak and a lower number of red maple were found on the scarified plots when compared to the control plots. The current study had similar trends to what was initially found in the aforementioned studies, but the current study's acorn germination percentages were not as high as found in Zaczek and others (1997). However, it is difficult to strictly compare the studies because they were not conducted in same region, the same species were not involved, predation pressure varied, and the stands did not have the same environmental conditions.

In addition to enhancing germination, the scarification treatment also played a role in reducing the poison ivy cover in the understory. The reduced competition should free up resources necessary for enhanced oak seedling growth.

The results after one year of this study look promising. The understory condition was more favorable than prior to scarification as scarified plots had more oak advanced regeneration present. With regard to seedling height distribution, it also appeared the oaks made up a favorable proportion of the regeneration cohort present one year after scarification. Because oak made up a more favorable proportion of the stems in the understory and did not have an over abundance of larger seedlings to compete with, the stand was in a better condition to be regenerated. One well accepted guideline about regenerating oak is that to ensure success large competitive advanced regeneration must be present in the understory prior to harvest (Crow 1988, Johnson and others 1989, Meadows and Stanturf 1997, Zaczek and others 1997, Larsen and Johnson 1998). It appears that the scarification has resulted in greater numbers of oak seedlings in an enhanced competitive position.

However, the oak seedlings present in the understory do not guarantee successful regeneration. Many factors are important to consider to ensure the future development of the regeneration currently present in the understory. An important factor controlling the survival of these seedlings is the understory light levels (Crow 1988, Nowacki and Abrams 1992) as cherrybark oak and post oak are intolerant of shade (Krinard 1990, Stransky 1990). Competing vegetation may also play a role in impacting the growth of the newly establish oak seedling reproduction. If oak growth is not rapid enough to extend above the competition, a regrowth of poison ivy over time may retard the development of these newly established seedlings. Likewise, repeated deer browsing may have a negative impact on these newly established seedlings (Lorimer 1993).

We suggest that manipulation of the midstory or overstory is likely necessary to alleviate some of the problems created by low light levels (Janzen and Hodges 1985, Loftis 1990). Without a release, the seedlings present will most likely not survive and leaving the stand in a condition similar to what was seen prior to the scarification treatment. However, even a release treatment does not guarantee the survival of this newly established regeneration cohort.

CONCLUSIONS

The purpose of this study was to determine the effects of shallow soil scarification, in the presence of abundant acorns, on the germination and first year survival in a mixed-oak bottomland forest. One year after treatment, the number of oaks was significantly greater in the scarified plots than in the control plots. The results suggest that the soil scarification treatment method used created more favorable conditions for increased acorn germination and oak seedling survival. The results gained from this study not only extend the knowledge of soil scarification as a tool to enhancing oak seedling reproduction, but also suggest that this silvicultural treatment may be a useful management tool when applied in bottomland oak stands.

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