AILANTHUS AND PRESCRIBED FIRE: IS IT A VOLATILE COMBINATION?

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Abstract—Throughout much of the Central Hardwoods region, the use of prescribed fire on public lands has increased rapidly in the last decade to improve oak regeneration. While prescribed fire can favor oak regeneration, its use may also increase risk of invasion and expansion of nonnative invasive species (NNIS). Although fire has often been shown to facilitate the expansion of NNIS in the Western United States, much less in known about the effects of fire on invasives in the Eastern United States. In 2008, a team of Ohio scientists and land managers initiated a Joint Fire Science Program (JFSP) project to study how the distribution and abundance of *Ailanthus altissima* (*Ailanthus*) relates to recent prescribed fires, harvesting activity, seed sources, and other landscape and stand characteristics. We found that recent timber harvest activity was the best predictor of *Ailanthus* presence; prescribed fire was not a good predictor. We also quantified the direct effects of prescribed fire on the demography of *Ailanthus* populations, with and without a pre-burn application of stem-injected herbicide. We found that after one prescribed fire, *Ailanthus* germinants and sprouts from topkilled saplings and trees were poor competitors with faster-growing post-fire woody regeneration as forest floor shading increased over time. This study demonstrates that prescribed fire alone does not appear to facilitate the spread of *Ailanthus*. These findings also suggest that further empirical studies are needed to address the combined impacts of fire and timber harvesting on *Ailanthus* invasions in eastern U.S. forests.

BACKGROUND—FIRE AND INVASIVE PLANT BIOLOGY

To best understand how woody invasives are impacted by fire and other management practices, it is crucial to know the individual life history traits of these plants. Invasive species often are prolific seed producers, which are either wind or animal dispersed; they typically reproduce at a young age; and they can often sprout prolifically (Marinelli and Randall 1996). Rebbeck (2012) summarized the biological and ecological traits of common nonnative invasive trees, shrubs and vines found in Eastern U.S. forests. Important traits to consider when evaluating a species of interest include: (1) level of shade tolerance, (2) dioecious or monoecious reproduction, (3) annual seed production rate, (4) mode of seed dispersal, (5) seed bank viability, (6) annual growth rate, (7) sprouting ability, (8) competitiveness, and (9) successional status. Unfortunately, there are numerous information gaps for many of the species (Gucker and others 2012, Rebbeck 2012).

Limited empirical data are available regarding how many invaders respond to fire in the Eastern United States, though more is known about fire and invasives in Western U.S. forests and grasslands. Huebner (2006) evaluated 17 common nonnative invasive species (NNIS) for their response to fire and their potential to change current fire regimes in eastern oak communities and reported that most of the woody species evaluated have the potential to be resistant of fire at maturity. These included autumn olive *(Elaeagnus umbellate*), common buckthorn (*Rhamnus cathartica*), Japanese and bush honeysuckles (*Lonicera* spp.), kudzu (*Pueraria montana* var. *lobata*), multiflora rose (*Rosa multiflora*), Norway maple (*Acer platanoides*), and privet (*Ligustrum japonicum*). The response of *Ailanthus* to fire was not studied directly, but *Ailanthus* was predicted to endure and/or increase because of its ability to sprout. While updating the U.S. Forest Service Fire Effects Information System, Gucker and others (2012) characterized the information available on fire and invasive plants in the Eastern United States.

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They found that often information relevant to fire was anecdotal and that observation-based information was sparse. The group concluded that more experiments and observations are needed, including collecting several years of data in a particular ecosystem, studying different burning conditions at varying times of year with varying fire severities, and varying intervals between burns. The authors' primary message was that "more high-quality information is needed for fire managers to avoid exacerbating problems with invasive plant species." We do know that fires often topkill vegetation that later resprouts prolifically, increase light levels within forest stands, and consume leaf litter, which releases nutrients and exposes mineral soils. These forest floor changes typically favor germination and seedling establishment, with opportunistic NNIS often getting a jump start on the native species if seed sources are present. Soil disturbances resulting from the installment of fire breaks can also promote NNIS establishment. The use of dozers, tankers, and all-terrain vehicles may introduce seeds of NNIS into previously non-infested areas. Because the current state of fire and invasive plant species research in Eastern U.S. forests is very limited, anecdotal information is currently being used by managers.

Adding to the challenge of utilizing prescribed fire and other management practices to promote oak regeneration is the fact that some invasive plants are, like oaks, disturbance-dependent species. They can share similar life history traits (e.g., strong sprouters, well-developed root systems, and drought tolerance), making it a challenge to promote oaks while minimizing the establishment and growth of native and nonnative competitors. *Ailanthus* represents one such woody invasive species. Prescribed fire topkills stems and promotes resprouting of both oaks and nonnatives. When developing a management strategy, it is important to link the timing of treatments to the phenology and energy storage patterns of the targeted species. To be most effective, managers need to find the "Achilles heel" of the target species and treat it when it is most vulnerable. An effective management plan should connect the timing of fire and/or cutting to periods of low energy reserves in roots to reduce or eliminate subsequent sprouting. Since maximum starch accumulation occurs in late summer to early fall for most species, this would not be an effective time to burn. Conversely, rapid mobilization of root starch reserves occurs in the spring when plants are producing new leaves, but successful implementation of spring prescribed fires can be challenging because of typically narrow burn windows. The timing of leaf-out can vary considerably with species. Bush honeysuckles are typically the first to leaf out in the spring and the last to drop leaves in the fall, while oaks are late to leaf out and retain leaves well into late fall. Huddle and Pallardy (1999) investigated the impact of burn season on survival, growth, and root starch of 1- and 2-year-old red maple, white oak, and red oak seedlings. They found no difference in survival among species after a fall burn (pre-leaf drop). In contrast, red oaks survived spring fires (after leaf-out) better than maple seedlings because of higher resprouting of oaks, which was attributed to higher root starch levels. This same physiological approach is recommended when determining the most effective time to implement a prescribed burn or treat NNIS with herbicides. Late summer and early fall is the ideal time for stem injections to promote translocation of herbicide to roots to prevent resprouting of woody NNIS, but we do not recommend it as an effective season to burn.

Another important component for any land management plan is to have a current inventory of NNIS within the area of interest. Before implementing a harvest or prescribed fire program, it is crucial to be proactive regarding nonnative invasive plants before that first tree is cut or fire line is installed. Managers need to know what nonnative species are present, and where and in what numbers they are found, both within and nearby units where prescribed fires are planned. Unfortunately, managers are often lacking adequate resources to conduct NNIS inventories and to treat infested sites. A worst-case scenario would be the creation of a NNIS monoculture within a landscape with little to no ecological or economic value. In 2003, our group witnessed the abundant establishment of *Ailanthus* seedlings following a thinning and prescribed fire treatment installed in one of three southeastern Ohio State forests as part of the national Joint Fire Science Program (JFSP) Fire and Fire Surrogate Study (Rebbeck 2012, Rebbeck and others 2005). It appears that the combination of an ample seed source in the stand along with soil and canopy disturbances during treatment installation caused the surge in *Ailanthus* seedlings. This was further supported by a post-treatment inventory that found few if any adult female *Ailanthus* present in the two adjacent treatment units (shelterwood only and burn only), where no large post-treatment increase in *Ailanthus* was observed.

We learned valuable lessons from the consequences of that study. First, early detection of NNIS in advance of a disturbance is critical to limit the establishment of invasives after the disturbance. Second, it would have been advantageous to remove the seed source with an herbicide treatment prior to the prescribed burn. Had we known the extent of infestation in advance, those observed impacts could have been mitigated prior to thinning and burning. That post-disturbance increase in *Ailanthus* did, however, initiate the development of an active partnership between land managers and researchers that focuses on learning where *Ailanthus* is found on a large forested landscape, developing a cost-effective mapping tool, identifying predictors of its presence in these forested

landscapes, and how *Ailanthus* responds to prescribed fire. Our overarching goal is to develop strategies that will help limit the expansion of *Ailanthus* while also sustaining oak in a managed forest landscape.

SUCCESSFUL MANAGER–RESEARCHER COLLABORATION

In 2008, the JFSP sought research proposals that specifically addressed the interaction of invasive plants and fire in the Eastern United States. We successfully secured funding and developed a series of forest management questions related to the use of prescribed fire and invasive plants focusing on the prolific sprouter and seed producer, *Ailanthus*:

1. Can prescribed fire be used effectively without facilitating the spread of NNIS?
2. Can prescribed fire be used as a surrogate for herbicide treatment of NNIS?
3. Can herbicide and fire treatments be combined to enhance control of NNIS?
4. To what extent does fire interact with timber harvesting and natural disturbances to promote the establishment and spread of NNIS?

Our two research objectives were to determine the distribution and abundance of *Ailanthus* across a managed forest landscape (Tar Hollow State Forest) and quantify the direct effects of prescribed fire on *Ailanthus* populations. The forest has a long history of timber harvesting and farming since European settlement in the late 1700s. Following a Federal land resettlement program in the 1930s, a public forest was established. It is reforested with both artificial and natural regeneration of mixed oak and mixed mesophytic species. It currently has an active timber harvesting program, and since 2001, an active prescribed burn program. Based on dendrochronological records, *Ailanthus* has been present on Tar Hollow since the early 1930s.

The first task of the project was to efficiently identify seed-bearing female trees across the forested study area. We chose to aerially map *Ailanthus* during the dormant season, when the visibility of its persistent seed clusters is most prominent (fig. 1). We utilized a Bell 206 B3 JetRanger helicopter owned by the Ohio Department of Natural Resources (ODNR) Division of Wildlife. ODNR Division of Forestry personnel conducted the aerial survey using georeferenced digital aerial sketch mapping technology developed to conduct forest health surveys (Schrader-Patton 2003) (fig. 2). Approximately 9,600 acres of highly dissected forested land was mapped in a little more than 2 hours. Through a partnership with the ODNR Division of Forestry and the Wayne National Forest, we continue to refine our mapping tool, and subsequently have identified *Ailanthus* infestations in more than 500,000 acres of public forests in Ohio. Coordinates from these surveys were used to produce infestation maps for further management planning and are easily downloaded to hand-held global positioning system (GPS) units to be used by field crews to locate *Ailanthus* trees for chemical or other treatments. The method is proving to be a highly effective and efficient tool to map the distribution of *Ailanthus* seed sources in large landscapes. A typical survey, including rental of helicopter time, costs approximately $0.40 per acre. A manuscript that describes the mapping methodology in detail is currently in preparation.

In addition to the aerial mapping of seed-bearing female trees, we installed a systematic grid of research plots within the 9,600-acre study area to quantify the following: abundance, size, and age distribution of *Ailanthus*; proximity to *Ailanthus* seed sources; timber harvest history; fire history and intensity; canopy structure; and a suite of landscape features such as slope, aspect, and soil properties. Approximately 2,100 acres of the study area had been burned between 2001 and 2009. Forest Service scientists and research technicians were given full access to ODNR timber harvest records from the study area; records were digitized and incorporated into a geographic information system (GIS) database. Current data analysis includes the development of a GIS-based model of key factors to predict the presence of *Ailanthus*. To date, more than 60 variables have been tested in models. Fire history was not a significant predictor of *Ailanthus* presence; the best predictor of *Ailanthus* presence was whether a timber harvest had occurred within the last 25 years. Canopy structure was also important, with more open mid-canopies favoring *Ailanthus*. Plans are underway to validate the predictive model of *Ailanthus* on the Wayne National Forest in southeastern Ohio.

The second objective of this collaboration was to document the direct effects of prescribed fire on *Ailanthus*. To date, no previous work on the direct effects of fire on *Ailanthus* has been published. We implemented a replicated study at Tar Hollow State Forest to determine if an herbicide treatment in advance of a prescribed burn would limit *Ailanthus* expansion after fire. Treatments included control (no herbicide, no burn), burn only, herbicide only, and herbicide + burn. *Ailanthus* stems (≥1 inch diameter at breast height [dbh]) were stem-injected (hack-n-squirt) with imazapyr (6.25% of Arsenal®AC [53.1% a.i.]) the fall prior to a spring burn. Three years post-treatment, 91 percent of the herbicide-only and 95 percent of herbicide + burn treated *Ailanthus* stems 4 inches dbh and larger were dead with no resprouting. However, in the burn-only plots,

Ailanthus mortality was only 37 percent of stems 4 inches dbh and larger. In the first postfire growing season, small sprouts (up to 1 inch dbh) and newly-germinated *Ailanthus* seedlings increased three- to four-fold in the burn-only and herbicide + burn treatments. After three growing seasons, those numbers dropped to preburn levels because these smaller stems competed poorly with other vegetation such as the nonnative wineberry (*Rubus phoenicolasius),* native blackberry (*Rubus* spp.*)*, and herbs that were also stimulated by the fire. A second prescribed burn is planned for 2014 to assess the impacts of multiple fires on *Ailanthus* populations in mixed oak forests.

SUMMARY

To summarize what we have learned about the interaction of fire and forest management practices and *Ailanthus* from this collaborative project, let us revisit our initial questions:

- What are the direct effects of fire on *Ailanthus*? A single mid-April prescribed fire stimulated both *Ailanthus* seed germination and sprouting. However, new *Ailanthus* germinants and small sprouts did not persist in subsequent years because of competition with other vegetation. We are in the process of studying the impact of multiple burns on *Ailanthus* regeneration.
- Can prescribed fire be used effectively without facilitating the spread of *Ailanthus*? Perhaps, but further long-term study is needed. Timber harvesting within the last 25 years appears to be more important in facilitating the spread of *Ailanthus* than a history of fire, as indicated in our GIS-based modeling.
- Can prescribed fire be used as a surrogate for herbicide treatment of *Ailanthus*? Given the results of this single study, the use of prescribed fire alone should not be considered as an alternative to herbicide to control *Ailanthus*. Although fire topkills *Ailanthus*, postfire sprouting is prolific.
- Can herbicide and fire treatments be combined to enhance *Ailanthus* control? The two treatments combined were very effective in killing and preventing the sprouting of large saplings (>1 inch dbh) and *Ailanthus* trees (≥4 inch dbh).
- How does fire interact with timber harvesting and natural disturbances to promote establishment and spread of *Ailanthus*? We have just begun to study the interactions of timber harvesting and natural disturbances on *Ailanthus* populations. Factors that predict *Ailanthus* presence in forests are emerging. However, more collaborative landscape level studies between land managers and researchers are needed across the Eastern United States.

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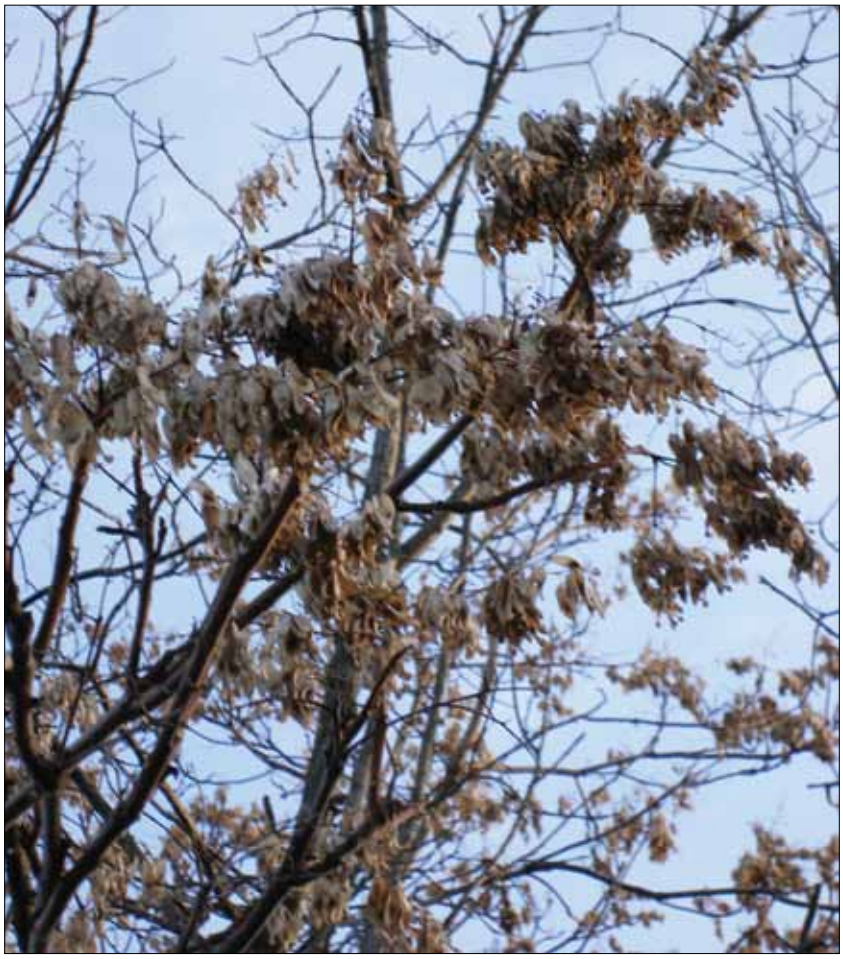

Figure 1—Dormant growing season view of seed clusters on adult female *Ailanthus* tree.

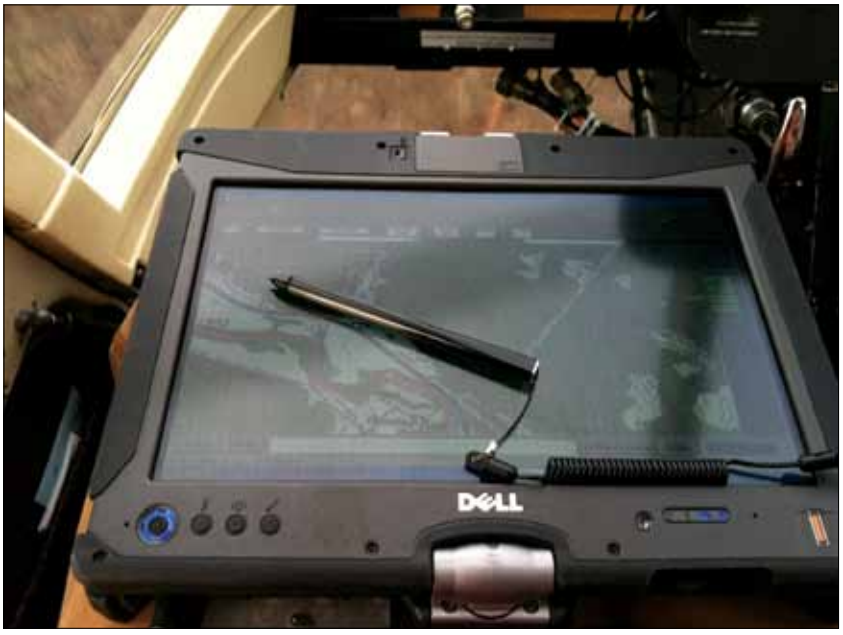

Figure 2—Digital sketch mapping software tablet used to survey female *Ailanthus* during helicopter surveys.