The Ecology of Garlic Mustard in Eastern Hardwood Forests

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Abstract

Upwards of 25% of the plant species in many eastern floras have been introduced. Many of these species have become invasive. Many of the worst invasives are native to Eurasia and were brought to the U.S. either intentionally for forage, fiber production, erosion control, ornamentals, or unintentionally via crop seed contaminant, transportation, or nursery stock. Typical examples include multiflora rose (*Rosa multiflora* Thunb.; Rosaceae), kudzu (*Pueraria lobata* (Willd.) Ohwi; Fabaceae), autumn olive (*Eleagnus umbellata* Thunb.; Eleagnaceae), purple loosestrife (*Lythrum salicaria* L.; Lythraceae) and Japanese and Amur honeysuckles (*Lonicera japonica* Thunb. and *L. maackii* (Rupr.) Maxim.; Caprifoliaceae). New species are being constantly added to the list as botanists and ecologists recognize new and emerging threats.

Attempts to characterize the life-history of these species has been hindered by the broad array of species and different phylogenetic origins. Many, but not all, of the most problematic species have small, easily dispersed seed that has few germination requirements and is able to maintain a seedbank once established. These species often exhibit rapid growth, vegetative reproduction, and considerable phenotypic plasticity. In addition, the pollination syndrome is often generalized or abiotic, and many of the species are self-compatible. All of these traits aid in the establishment and growth of these non-native species in their new environments.

Likewise, attempts to characterize and make generalizations regarding invaded habitats is also complicated by the individualistic nature of the species and habitats involved. Some have suggested that old-growth forests may be less susceptible to invasion due to increased stability. Ecosystems with frequent breaks in their cover, due to natural or anthropogenic disturbances, may be more susceptible to invasion. The data to support these suggestions and observations is scant.

Garlic mustard (*Alliaria petiolata* [Bieb.] Cavara & Grande; Brassicaceae) is an invasive species that has now made it on to many of the eastern U.S. most problematic species lists. It shows many of the characteristics of weedy species, including: self-compatibility, high fecundity (5,000-20,000 seeds m^{-2}), seed viability >95%, dispersal by gravity & water, maintains a seedbank from 1-5 years, and requires only 100d of cold stratification for germination (most likely factor limiting southern migration). Throughout most of the U.S., the species has an obligate biennial life-cycle. The seeds are dispersed during mid-summer, they are cold-stratified over the following winter and germinate in the early spring; during their first summer they grow as a basal rosette and maintain that form over the second winter; they will bolt during the spring of the following year, flower, set seed, and repeat the cycle. Curiously, the species has a growth habit which is completely different in its natural and invaded ranges. In its natural range, the species usually grows in a solitary fashion and is quite unassuming. In the eastern U.S., the species often grows quite robustly in very dense patches and will spread to occupy large patches in a variety of shaded and open habitats.

My lab embarked upon a series of studies to evaluate various aspects of the ecology, genetics, and biogeography of garlic mustard. One of my first studies with this species (McCarthy 1997) was designed to evaluate the community level impact of this species in a heavily infested floodplain. Garlic mustard was removed from paired plots (vs. control) and the response in understory species diversity and abundance monitored for three years. Plots with garlic mustard removed showed an increase in native species diversity and overall compositional change. Responses were most pronounced among annuals and woody perennials (the latter was unexpected). This experiment demonstrated community level suppression of native species by garlic mustard. Subsequent experiments were designed to evaluate the mode of interference (competition vs. allelopathy).

We assessed the allelopathic potential of garlic mustard on seed germination and seedling establishment via two experiments utilizing a dilution series of shoot and root extracts (McCarthy and Hanson 1998). Regardless of extract concentration or seed type, seed germination was largely unaffected by garlic mustard extracts. Only one target species exhibited slight inhibition of seedling growth when watered with the most concentrated

dilution of garlic mustard extract. Overall, we concluded that allelopathy does not have a strong direct effect in its interference with other species. However, a subsequent competition experiment did demonstrate a strong competitive effect of this species on native species, even amongst newly germinating oak seedlings (Meekins and McCarthy 1999). Garlic mustard was shown to be very aggressive and able to capture considerable resources.

Subsequently, we embarked upon a molecular-based population genetic and biogeographic study to evaluate the likely origin of garlic mustard and to assess its genetic diversity (Meekins et al. 2001). Using inter-simple-sequence repeat (ISSR) analysis of populations from Europe and the U.S. we found that there was a strong match between our Scottish (putative source) population and many populations in the central Appalachians. But, there have likely been a number of introductions from different sources. We also found strong population structuring, with the greatest variance among populations (61%) compared to between continents (16%) and within populations (23%).

The two most recent studies on garlic mustard were designed to evaluate what resource levels garlic mustard requires to grow and reproduce and to assess how this relates to habitat invasibility and spread. In Meekins and McCarthy (2000) we employed a complete factorial design (manipulating density, nutrients, and light) and determined that site fertility may play a role in invasion and establishment. Moreover, light availability may be the most critical factor in producing large, highly fecund individuals that could spread to dominate an otherwise intact understory. We then brought these results in to a field experiment, to examine invasion success at forest edges (vs. interior) in upland and lowland habitats. Litter disturbance was also applied to evaluate localized biotic effects and light availability on seed germination. While litter disturbance showed no effect, moist lowland sites and edge habitats were quite susceptible to establishment and growth of garlic mustard (Meekins and McCarthy 2001).

In conclusion, garlic mustard appears to behave quite differently in its native and invaded populations, despite the qualitatively similar habitat and genetic structure. The species appears to be quite plastic, readily able to capture resources, and aggressively competitive. Allelopathy does appear to be a strong factor in structuring invaded plant communities. Despite its ecological amplitude, garlic mustard responds rapidly to high light conditions on fertile sites. Because the species does negatively affect community structure, control should be attempted, but probably in a triage fashion. Lower quality, closed canopy sites will be easier to control than highly fertile sites with open canopies (or edges) and higher light conditions.

Literature Cited

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