Alliaria petiolata

Adapted from: ELEMENT STEWARDSHIP ABSTRACT

prepared by
Victoria Nuzzo
Native Landscapes
1947 Madron Road
Rockford, IL 61107-1716

(May 1994)

SUMMARY

Garlic mustard (*Alliaria petiolata*) is a biennial herb that invades forested communities and edge habitats, where it spreads rapidly and apparently displaces native herbaceous species, often within ten years of establishment. The plant has no natural enemies in North America, and is difficult to eradicate once established. Thus, the best and most effective control method for *Alliaria* is to prevent its initial establishment.

In shaded and partially shaded communities lacking *Alliaria* the preferred method is to monitor annually, and remove all *Alliaria* plants prior to seed production. Once *Alliaria* is established, the management goal is to prevent seed production until the seed bank is depleted, potentially 2-5 years. Cutting of flowering stems provides the most effective control with minimal or no side effects, but has a high labor cost. Burning and herbicide application both provide effective control at a lower labor cost, but each has potential drawbacks: Fire may increase total presence of *Alliaria* unless a second and third consecutive fire are conducted; fire may alter groundlayer composition; and herbicides may negatively impact some native groundlayer species.

BIOLOGY

Alliaria petiolata [(M. Bieb.) Cavara and Grande] is an obligate biennial herb of the mustard family (Brassicaceae). The genus name *Alliaria* refers to the garlic or *Allium*-like fragrance of the crushed leaves, an unusual odor for the mustard family. The species name *petiolata* refers to the petiolate leaves.

Alliaria seeds germinate in early spring, beginning in late February or early March, and concluding by mid May in northern states and Canada (Cavers et al. 1979, Kelley et al. 1991, Roberts and Boddrell 1983). In northern Illinois, germination coincides with emergence of spring beauty (*Claytonia virginica*) and false mermaid weed (*Floerkea proserpinacoides*).

Seedling density in heavily infested forests was recorded at 5,080/m^2 at the cotyledon stage, and 2,235/m^2 at the 2-3 leaf stage, in Illinois (Nuzzo unpublished), and approximated at 20,000/m^2 in Ohio (Trimbur 1973).

By June seedlings develop the characteristic rosette of first year plants. Basal leaves are dark-green and kidney-shaped with scalloped edges, 6-10 cm diameter, and have pubescent petioles 1-5+ cm long (flowering stem leaves are alternate, sharply-toothed, triangular, 3-8 cm long and wide, and gradually reduced in size towards the top of the stem).

Immature plants can be confused with other rosette forming species, especially violets (*Viola* sp.), white avens (*Geum canadense*), and *Cardamine* sp. *Alliaria petiolata* can be distinguished from these plants by the strong garlic odor in spring and summer. In fall and winter *Alliaria* can be distinguished by examining the root system. *Alliaria* has a slender, white, taproot, with a distinctive "s" curve at the top of the root, just below the root crown. Axillary buds are produced at the root crown and along the upper part of the "s."

First year rosettes are sensitive to summer drought (Byers 1988) and approximately 95% die by fall (Nuzzo 1993b). By mid-fall rosettes average 4-10 cm diameter and are dark green to purplish in color. The rosettes continue to grow in winter during snow-free periods when temperatures are above freezing (Cavers et al. 1979). Natural mortality continues through winter: Total survival rate from seedling to adult stage varies from 1% (Nuzzo 1993b) to 2-4% (Cavers et al. 1979).

Alliaria is an obligate biennial: all plants that survive the winter produce flowers, regardless of size, and subsequently die (Cavers et al. 1979, Byers and Quinn 1988, Bloom et al. 1990). Plants only 5 cm tall, with 3-4 leaves, have been observed with flowers and seeds. The majority of plants are taller, averaging 0.7 to 1.0 m when in flower. Flower stalks begin to elongate in March or April, and flowers open early April through May. This is some 6-10 weeks after new seedlings germinate; in established populations generations overlap, and two cohorts can be seen from March through June. *Alliaria* flowers can be self-or cross-pollinated (Cavers et al. 1979, Babonjo et al. 1990).

Plants usually produce 1-2 flowering stems, although robust plants have been recorded with up to 12 separate flowering stalks. Flowers are produced in spring in terminal racemes, and occasionally in short axillary racemes. Some plants produce additional axillary racemes in mid-summer. Flowers are typical of the mustard family, consisting of four white petals that narrow abruptly at the base, and 6 stamens, two short and four long. Flowers average 6-7 mm in diameter, with petals 3-6 mm long. Seeds develop in a linear silique, with siliques forming on the lower part of the inflorescence while flowers are still opening on the upper part. *Alliaria* produces an average of 16.4 ($\pm$ 3.0) seeds/silique (range 3 to 28), and 21.8 ($\pm$ 22.5) siliques/plant (range 2 to 422; Nuzzo unpublished, Cavers et al. 1979). Seeds ripen and disperse between mid-June and late September (Cavers et al. 1979, Kelley et al. 1990).

Seeds are dormant at maturity and require 50 to 100 days of cold stratification to come out of dormancy (Byers 1988, Lhotska 1975, Baskin and Baskin 1992). The dormancy period lasts eight months in southern locales (Baskin and Baskin 1992, Byers 1988) and 22 months in northern areas (Cavers et al. 1979).

Unlike some forest crucifers that fail to germinate under leaf cover, *Alliaria* seeds germinate in both light and dark after dormancy is broken (Bloom et al. 1990, Byers 1988). Light alone will not stimulate germination during cold stratification (Byers 1988). The majority of seeds germinate as soon as dormancy is broken (Roberts and Boddrell 1983, Baskin and Baskin 1992). A small percentage of seed remains viable in the seed bank for up to four years (Roberts and Boddrell 1983, Baskin and Baskin 1992).

Alliaria spreads exclusively by seed (Cavers et al. 1979). Seeds typically fall within a few meters radius of the plant. Wind dispersal is limited, and seeds purportedly do not float well, although seeds readily attach to moist surfaces (Cavers et al. 1979). Anthropogenic distribution is the primary dispersal mechanism (Lhotska 1975, Nuzzo 1992b, 1993a). Seeds are transported by natural area visitors on boots and in pant cuffs, pockets, and hair, and by roadside mowing, automobiles and trains (Nuzzo 1992b). Seeds are widely dispersed in floodwaters. Seeds may be dispersed by rodents or birds; isolated plants are frequently found at the bases of large trees in forest interiors. Seeds may possibly be distributed directly or indirectly by white-tailed deer (*Odocoileus virginianus*).

In southern locales *Alliaria* populations are even-aged, alternating annually between immature plants and adult plants (Baskin and Baskin 1992), probably due to the 8 month seed dormancy. In northern climates *Alliaria* populations can be even-aged in early stages of invasion, and then become multi-aged as the seed bank builds up. *Alliaria* is frequently overlooked at low density levels. In many sites *Alliaria* can be present for a number of years before appearing to "explode" in favorable years. Once *Alliaria* reaches this level of infestation control is difficult to achieve.

IMPACTS

Alliaria is one of the few alien herbaceous species that invades and dominates the understory of forested areas in North America. The phenology is typical of cool-season European plants, and *Alliaria* grows rapidly during early spring and late fall when most native species are dormant. *Alliaria* invades forested communities and edge habitats, where it spreads rapidly and apparently displaces native herbaceous species, often within ten years of establishment. After just four years of co-occurrence with *Alliaria*, cover of the ephemeral herb toothwort (*Dentaria laciniata*) was reduced >50% (Nuzzo 1992a). Toothwort plants associated with *Alliaria* were stunted, yellowed, and failed to flower.

HABITAT

Alliaria is most widespread in the midwestern and northeastern United States and in southern Ontario, where it invades wet to dry-mesic deciduous forest (Cavers et al. 1979, Nuzzo 1992a, 1993a), and also occurs in the partial shade characteristic of oak savanna, forest edges, hedgerows, shaded roadsides, and urban areas, and occasionally in full sun (Nuzzo 1991). *Alliaria* is common in river-associated habitat, particularly in the Northeast (Nuzzo 1993a), and in both upland and floodplain forest communities in the Midwest.

Alliaria grows on sand, loam, and clay soils, and on both limestone and sandstone substrates, occurs rarely on drained peat soils, and does not occur on muck soils. *Alliaria* frequently grows in well-fertilized sites (Cavers et al. 1979), and is described as a nitrophile by Passarge (1976) and Wilmanns and Bogenrieder (1988).

MANAGEMENT

The goal of *Alliaria* management is to prevent seed production. *Alliaria* spreads only by seed, and has a short-lived (2-5 years) seed bank; in theory, preventing seed production for a maximum period of five years should result in elimination of *Alliaria* from a site, if no additional seeds are introduced.

The primary management objective in areas lacking this plant is to prevent establishment, by annually monitoring for and removing all *Alliaria* plants. The primary management objective in infested sites is to prevent seed production. Cutting flowerstalks is effective in small populations. Fire and herbicides are useful for larger populations but both have potential side effects. No method provides 100% control.

Growing season mortality reduces *Alliaria* seedling populations by >95% between spring and late fall (Nuzzo 1993b); hence, control is most economical when undertaken in late fall or early spring, prior to flower production. Late fall is usually the preferred season for control, as native plants are dormant and management can be conducted until snow covers the ground. If weather is unfavorable in fall, control can still be conducted in early spring. Delaying control until spring can be risky, as native herbs may begin growth earlier than anticipated, and weather may limit or prevent management activities.

Biological control may be the only regionally effective method of controlling this species, but as of 1997 no formal program had been established.

BURNING

Prescribed burning can provide effective control of *Alliaria* when fires burn completely through the affected area, and are conducted for at least two consecutive years (Nuzzo 1991). Kill appears related to a critical increase in rootcrown temperature, effected by a slow fire, or by a fast fire that also removes all litter.

Low-intensity fires are ineffective (Nuzzo 1991). A slow mid-intensity fire can reduce adult density by 50% (Nuzzo 1991). A fast high-intensity fire that removes most litter can effectively reduce adult cover (Nuzzo et al. 1996). However, fast fires may leave a thin layer of litter. This 1-2 cm layer is sufficient to protect root crowns, which subsequently produce multiple flower stalks from axillary buds, increasing total seed production (Nuzzo et al. 1996). Removal of the litter layer increases seedling survival after fire, and can result in a larger population after a single burn (Nuzzo et al. 1996). Thus, after a single fire, total *Alliaria* cover can increase due to survival of adult plants, and/or to enhanced seedling survival. After two consecutive fires total cover is greatly reduced (Nuzzo et al. 1996).

Spring and fall fires are equally successful in reducing cover of *Alliaria* rosettes (Nuzzo 1991). Spring fires also reduce seedling presence if conducted during the germination period (Nuzzo 1991). However, burning enhances survival of seedlings that germinate after fire, by removing the smothering leaf litter (Nuzzo et al. 1996).

Use of fire as a management tool should be tailored to the specific community. Removal of the litter layer may facilitate invasion by disturbance adapted species, including *Alliaria*, particularly if there is little native groundlayer present at the site. Fires should only be conducted when at least two consecutive fires can be scheduled; burning only once may increase *Alliaria* abundance. Impact of consecutive fires on the community should be considered, including changes in groundlayer composition.

Fire is not a realistic management tool in upland communities that have become fire-resistent, due to decreased fuel loads and flammability resulting from replacement of overstory oaks (*Quercus* sp.) by cherry (*Prunus serotina, P. virginiana*), ash (*Fraxinus* sp.), black walnut (*Juglans nigra*), and hackberry (*Celtis occidentalis*). Invasion of the understory by buckthorn (*Rhamnus cathartica*) and honeysuckle (*Lonicera tatarica, L. xylosteum*) also reduces fuel loads.

CHEMICAL

Dormant season herbicide application can provide effective control of *Alliaria*, but poses a potential threat to native herbaceous and graminoid species.

Round-up

Round-up (glyphosate) applied at 1%, 2%, and 3% concentrations to dormant rosettes in late fall or early spring reduced adult cover by >95% (Nuzzo 1991, 1996). Control was slightly greater with higher Round-up concentrations. Seedlings that germinate after application are not affected by the herbicide, as Round-up has no soil residual. Roundup applied after germination will significantly reduce seedling populations (Nuzzo 1991).

Round-up results in some native species loss, particularly when applied in spring, as it is a non-selective herbicide. Semi-evergreen species including phlox (*Phlox divaricata*), wild ginger (*Asarum canadense*) and sedges (*Carex* sp.) are reduced by Roundup (Nuzzo 1996). At the community level, Round-up did not affect mean species richness or total mean herbaceous cover, but did significantly reduce cover of both sedges and grasses, at both 0.5% and 1% concentrations (Nuzzo 1996).

Basagran

Growing season application of Basagran (Bentazon) at 0.56-1.12 kg AI/ha (0.50-1.0# AI/acre) reduced rosette cover by 90-95% (Nuzzo 1994). Dormant season application nonsignificantly reduced rosette cover >90% (compared to 70% reduction in the control plots)(Nuzzo 1996).

Basagran did not affect species richness or herb cover, and had minimal effect on graminoid cover. *Alliaria* seedlings were not affected by treatment. Basagran is a post-emergent contact herbicide that targets dicots and is used to control mustards in agricultural fields.

CUTTING

Cutting flowering plants at ground level results in 99% mortality, and eliminates seed production. Cutting at 10cm above ground level results in 71% mortality and reduces seed production by 98%

(Nuzzo 1991). Ability of cut flowerstems to form viable seed is unknown. Cavers et al. (1979) suggest that vivipary (germination of seeds while still in the silique) does not occur, although all seeds remained viable during the observation period. Until more information is available, cut stems should be removed from the site, or piled and composted.

Cutting with a weed whip provides quick removal of flowering stems, but also may remove other desirable species. Some native species, such as *Trillium*, are severely impacted if cut. Most other species are not substantially damaged, and the benefits of removing *Alliaria* outweigh the temporary reduction in growth and reproduction of native groundcover species.

Pulling is very labor intensive but effective if the upper half of the root is removed. *Alliaria* frequently snaps off at or just below the root crown when the flower stalk is pulled, leaving adventitious buds which send up new flower stalks. Pulling can result in substantial soil disturbance, damaging desirable species and bringing up *Alliaria* seeds from the seedbank. Soil should be thoroughly tamped after pulling to minimize chances for re-establishment of garlic mustard or other weedy species. Alternatively, soil may be kept disturbed to stimulate germination of *Alliaria* seeds and subsequent depletion of the seedbank, if seedlings are removed before maturing. In general, cutting is a less destructive method of control than pulling but is effective only during flower stalk elongation, whereas pulling can be conducted throughout the growing season.

REFERENCES

Babonjo, F., S.S. Dhillion and R.C. Anderson. 1990. Floral biology and breeding system of garlic mustard (*Alliaria petiolata*). Abs. Transactions Illinois State Academy of Science, supplement to Volume 83:32.

Baskin, J.M. and C.C. Baskin. 1992. Seed germination biology of the weedy biennial *Alliaria petiolata*. Natural Areas Journal 12:191-197.

Bloom, C.T., C.C. Baskin, and J.M. Baskin. 1990. Germination ecology of the facultative biennial *Arabis laevigata* variety *laevigata*. American Midland Naturalist 124:214-230.

Byers, D.L. 1988. Life history variation of *Alliaria petiolata* in a range of habitats in New Jersey. M.S. thesis. Rutgers University, New Brunswick NJ. 132 p.

Byers, D.L. and J.A. Quinn. 1988. Plant size as a factor in determining flowering time and reproductive output in *Alliaria petiolata*. Abs. American Journal of Botany 75:71.

Cavers, P.B., M.I. Heagy and R.F. Kokron. 1979. The biology of Canadian weeds. 35. *Alliaria petiolata* (M. Bieb.) Cavara and Grande. Canadian Journal of Plant Science 59:217-229.

Kelley, T., S. Dhillion and R. Anderson. 1990. Aspects of the seed biology of garlic mustard (*Alliaria petiolata*). Abs. Transactions Illinois State Academy of Science, supplement to Volume 84:33.

Lhotska, M. 1975. Notes on the ecology of germination of *Alliaria petiolata*. Folia Geobotanica et Phytotaxonomica (Praha) 10:179-183.

Nuzzo, V.A. 1991. Experimental control of garlic mustard [*Alliaria petiolata* (Bieb.) Cavara & Grande] in northern Illinois using fire, herbicide and cutting. Natural Areas Journal 11:158-167.

Nuzzo, V.A. 1992a. Garlic mustard (*Alliaria petiolata* [Bieb.] Cavara and Grande) rate of spread and potential impact on groundlayer species. Report to the Illinois Department of Conservation. Native Landscapes. 17 p. + tables + figures.

Nuzzo, V.A. 1992b. Current and historic distribution of garlic mustard (*Alliaria petiolata*) in Illinois. Michigan Botanist 32:23-34.

Nuzzo, V.A. 1993a. Distribution and spread of the invasive biennial garlic mustard (*Alliaria petiolata*) in North America. pp 137-146 *in* McKnight, B.N., editor, Biological Pollution: the control and impact of invasive exotic species; proceedings of a symposium held at the Indiana University-Purdue University October 25 & 26 1991. Indiana Academy of Science. Indianapolis IN. 261 p.

Nuzzo, V.A. 1993b. Natural mortality of garlic mustard (*Alliaria petiolata* (Bieb.) Cavara and Grande) rosettes. Natural Areas Journal 13:132-133.

Nuzzo, V.A. 1994. Response of garlic mustard (*Alliaria petiolata* Bieb. [Cavara and Grande]) to summer herbicide treatment. Natural Areas Journal 14:309-310.

Nuzzo, V.A. 1996. Impact of dormant season herbicide treatment on the alien herb garlic mustard (*Alliaria petiolata* [Bieb.] Cavara and Grande) and groundlayer vegetation. Transactions Illinois State Academy of Science 89:25-36.

Nuzzo, V.A., W. McClain, and T. Strole. 1996. Fire impact on groundlayer flora in a sand forest. American Midland Naturalist 136:207-221.

Passarge, H. 1976. Uber schleier - und Staudengesellschaften mitteleuropaischer Ufersaume. Folia Geobot. Phytotax. (Praha) 11:137-162.

Roberts, H.A. and J.E. Boddrell. 1983. Seed survival and periodicity of seedling emergence in eight species of Cruciferae. Annals of Applied Biology 103:301-304.

Trimbur, T.J. 1973. An ecological life history of *Alliaria officinalis*, a deciduous forest "weed." M.S. thesis. Ohio State University. 56 pp.