

Mechanical
Control of
Japanese Knotweed
(*Fallopia japonica*
[Houtt.] Ronse
Decraene): Effects of
Cutting Regime on
Rhizomatous
Reserves

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Natural Areas Journal 17:341-345

ABSTRACT: Japanese knotweed, *Fallopia japonica* (Houtt.) Ronse Decraene, is an invasive exotic species that spreads by an extensive rhizome system but does not reproduce by seed outside of its native range. A series of greenhouse experiments explored the effectiveness of cutting as a control measure for this herbaceous perennial. We monitored patterns of biomass allocation to aboveground and belowground portions of uncut plants over a growing season, and performed cutting experiments to determine the effects on belowground biomass of cutting, timing of cutting, time interval between cuts, and multiple cuts. Allocation to belowground biomass was continuous during the growing season, with total belowground biomass exceeding aboveground biomass in the latter half of the growing season. Cut plants had significantly less belowground biomass accumulation at the end of the growing season compared to uncut controls. Rhizome biomass at the end of the growing season was inversely related to the number of cuts. With one, two, and three cuts, belowground biomass was 65%, 31%, and 13%, respectively, of uncut controls. Regression analysis predicted that a minimum of four cuts are needed during a single growing season to cause a net depletion of belowground biomass. The timing of cutting does not appear to be critical as long as it is done at least 7 weeks prior to senescence. Given its continuous allocation to rhizomes and its ability to sprout from as little as 7 g of rhizome, it is unlikely that *F. japonica* can be eradicated by cutting alone. However, cutting may be useful as an adjuvant to other methods of control.

Index terms: exotic plant, Japanese knotweed, *Polygonum cuspidatum*, *Reynoutria japonica*, weed management

INTRODUCTION

Fallopia japonica (Houtt.) Ronse Decraene (*Reynoutria japonica* Houtt., *Polygonum cuspidatum* Sieb. and Zucc., Japanese knotweed), an invasive exotic species, is recognized as a serious problem in the United Kingdom and parts of Europe and is increasingly a threat to natural areas in the United States. In North America and the United Kingdom, *F. japonica* generally grows in disturbed areas, along roadways, and, most commonly, along river banks. Invasion by *F. japonica* results in loss of wildlife habitat, decreased species diversity, and reduction of the water carrying capacity of rivers (Muenscher 1955, Conolly 1977, Beerling 1990, Gritten 1990, Welsh Development Agency 1991). *Fallopia japonica* has been observed as far north as Nova Scotia and Newfoundland; its range now extends throughout much of the eastern United States into North Carolina and Indiana, and it has been found in Washington and Oregon (Locandro 1973, Patterson 1976).

Fallopia japonica is a dioecious herbaceous perennial with an extensive system

of rhizomes that can grow more than 1 m in depth and 15–20 m in length (Locandro 1973, Conolly 1977). *Fallopia japonica* does not reproduce sexually where it has been introduced (Conolly 1977, Locandro 1978, Seiger 1993, Beerling et al. 1994). Instead, it regenerates from rhizomes and disperses from small rhizome fragments carried downstream or transported in soil by humans (Conolly 1977, Locandro 1978). *Fallopia japonica* can sprout from rhizomes even when buried up to 1 m (Locandro 1978) and is extremely persistent once established. The shoots, which emerge early in the growing season and may eventually reach over 4 m in height, limit the amount of light available to surrounding vegetation.

Although several herbicides are effective against *F. japonica*, herbicidal control may be inappropriate in conservation areas due to problems associated with lack of specificity, impact upon nontarget biota, and persistence in the soil (Ahrens 1975, Lynn et al. 1979, Scott and Marrs 1984, Beerling 1990, Gritten 1990, Palmer 1990). The most effective herbicides are unsafe for use in riparian areas, the primary hab-

itat of *F. japonica*, and other herbicides require repeated applications (Scott and Marrs 1984, Beerling 1990). The present study was undertaken in response to a request by the U.S. National Park Service to develop methods of controlling *F. japonica* without the use of herbicides.

Mechanical control has been used against a number of exotics and may be preferable to the use of herbicides where populations are relatively small, isolated, and easily accessible. Frequent cutting may control *F. japonica* by depleting stored reserves and removing photosynthetic tissue, thus restricting the growth of the rhizomes (Lynn et al. 1979, Leaky 1981, Palmer 1990). Scott and Mars (1984) found that cutting *F. japonica* in the field reduced aboveground biomass, but they concluded that cutting was an ineffective control strategy. However, their study involved cutting only once in a growing season and did not look at whether belowground biomass was affected by cutting aboveground biomass. Eradication of the rhizome system is necessary for effective control of *F. japonica* (Child et al. 1992).

Our study tested the efficacy of cutting off stems as a means of reducing rhizomatous reserves. We monitored the pattern of biomass allocation in uncut plants throughout a growing season, and performed cutting experiments to determine the effects of cutting, timing of cutting, time interval between cuts, and multiple cuts on belowground biomass.

METHODS

Seasonal Patterns of Biomass Allocation in Uncut Plants

Rhizomes approximately 1 cm in diameter were collected from established field populations in April 1989. The rhizomes were cut into 200 pieces, each three nodes in length. Each rhizome fragment was planted in a 20-cm-diameter plastic pot in a 3:1 mixture of commercially prepared topsoil and perlite. These transplanted rhizomes were grown outdoors under ambient temperature and light conditions. On June 5, after 60 days of growth, 40 randomly selected plants were

harvested. Thereafter, at 28-day intervals through September 25, additional groups of 40 randomly selected plants were harvested. Each harvested plant was separated into aboveground and belowground parts, rinsed with tap water to remove soil, dried at 40 °C, and weighed to the nearest 0.01 g.

Effects of a Single Cut at Different Times During the Growing Season

An additional 240 rhizome fragments were collected and grown as described above. After 60 days of growth, a group of 40 plants was treated by cutting stems at the soil level and removing the aboveground material. The cutting treatment was repeated on a different group of plants every 28 days between June 5 and September 25. As a control, 40 plants were left uncut. All plants were allowed to continue growth until the beginning of senescence (determined by the onset of leaf abscission). On October 15, 20 days after the last cut, all plants were harvested, separated into aboveground parts and belowground parts, rinsed, dried at 40 °C, and weighed to the nearest 0.01 g.

Effects of Varying the Number of Cuts, Time of Season in Which Cutting Occurs, and Time Interval between Cuts

We performed a third experiment in 1990 to determine whether the effect of cutting on belowground biomass varies with the number of cutting treatments, time interval between cutting, or the time of season in which cutting occurs. Two hundred and forty rhizomes were collected and grown as described above. Thirty plants were randomly assigned to each of eight groups: control, one cut (June, July, or August), two cuts (June and July, June and August, or July and August), and three cuts (June, July, and August). The experiment began in May and cuts were made at 28-day intervals, with the exception of plants cut in June and August (56 days apart). Following senescence (determined by loss of all leaves), all belowground parts were harvested and prepared as described above.

Statistical Analyses

Hartley's test was used to test for homogeneity of variances of normally distributed data. Data that were not normally distributed were tested for homogeneity of variances using a modified Levene test (Brown and Forsythe 1974, Snedecor and Cochran 1981, Day and Quinn 1989). Heteroscedastic data were log-transformed and then retested for homogeneity of variances. Log transformations corrected for heteroscedasticity in all cases.

There was some sample loss during final harvests, and unbalanced analyses of variance were used where appropriate. Log-transformed data from the biomass allocation study were analyzed using an unbalanced two-factor analysis of variance in a completely randomized design to determine whether aboveground or belowground biomass varied significantly over the season. Multiple comparisons were made using the Tukey-Kramer method ($\alpha=0.05$).

Log-transformed data from the 1989 cutting experiment were analyzed using a one-factor analysis of variance in a completely randomized design to determine whether belowground biomass at the end of the season varied among treatments. Multiple comparisons were made using the Tukey-Kramer method ($\alpha=0.05$).

Data from the 1990 experiment on effects of timing and frequency of cutting were log-transformed and analyzed using a one-factor analysis of variance in a completely randomized design to determine whether the amount of belowground biomass at the end of the season varied among the treatments. Multiple comparisons were made with the Tukey-Kramer method ($\alpha=0.05$). The multiple comparisons showed that groups of plants subjected to an equal number of cuts did not differ significantly from each other. Therefore, data from plants subjected to one cut were lumped, as were data from plants subjected to two cuts. A simple linear regression on untransformed data was used to determine the relationship between the number of cuts and the amount of belowground biomass remaining at the end of the season.

RESULTS

Seasonal Patterns of Biomass Allocation in Uncut Plants

Comparison of aboveground and belowground biomass from samples harvested at 4-week intervals throughout the growing season indicated that amount of biomass varied significantly by plant part and harvest date (ANOVA, $P < 0.05$). Belowground biomass increased significantly during each of the 4-week intervals throughout the growing season, from 2.99 g on June 5 to 47.46 g on September 25 (Figure 1). Aboveground biomass increased significantly between June 5 and August 28, but not between August 28 and September 25. In the early part of the season, significantly more biomass was present in stems and leaves than in rhizomes and roots, but by July 30 biomass did not differ between aboveground and belowground parts. By August 28, belowground biomass exceeded aboveground biomass.

Effects of a Single Cut at Different Times during the Growing Season

Belowground biomass at the end of the season varied significantly among cutting treatments (ANOVA, $P < 0.01$). Comparisons of means showed that belowground biomass of plants cut between June 5 and August 28 was significantly less than that of uncut controls (Figure 2). There was no significant difference among these four groups of cut plants with respect to belowground biomass. Belowground biomass of plants cut on September 25 did not differ significantly from that of uncut controls.

Despite the fact that plants cut between June 5 and August 28 had less biomass than uncut controls (43.45 g), they still had substantial rhizomatous biomass at the end of the growing season, 24 weeks after planting. The average belowground biomass of these plants was 30.67 g. This is comparable to the belowground biomass of the 20-week-old plants in the biomass allocation study (31.44 g) and considerably more than the belowground biomass of 8-week-old plants in that study (2.99 g). Plants from the biomass allocation study are a fair basis for comparison because

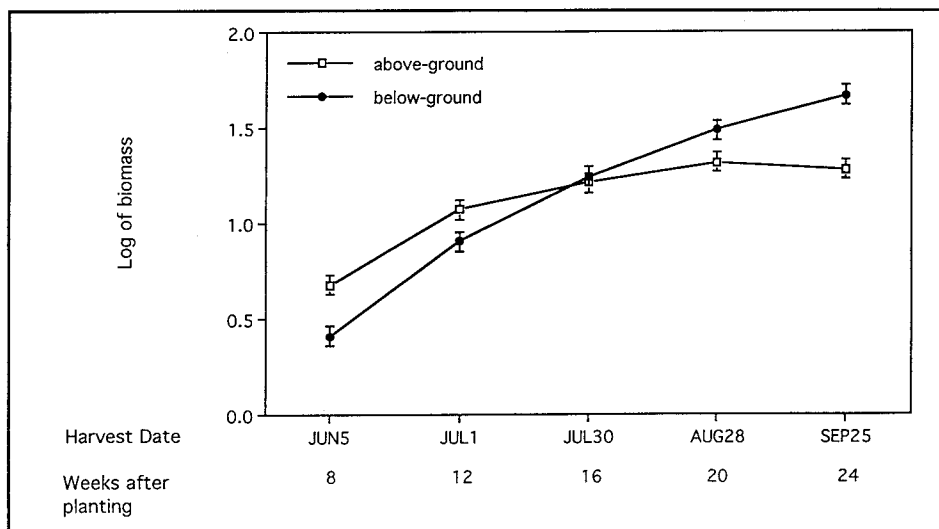


Figure 1. Aboveground biomass and belowground biomass in plants harvested at 4-week intervals throughout the growing season. Means are presented with Tukey's W confidence intervals for plant part by date interaction ($\alpha = 0.05$).

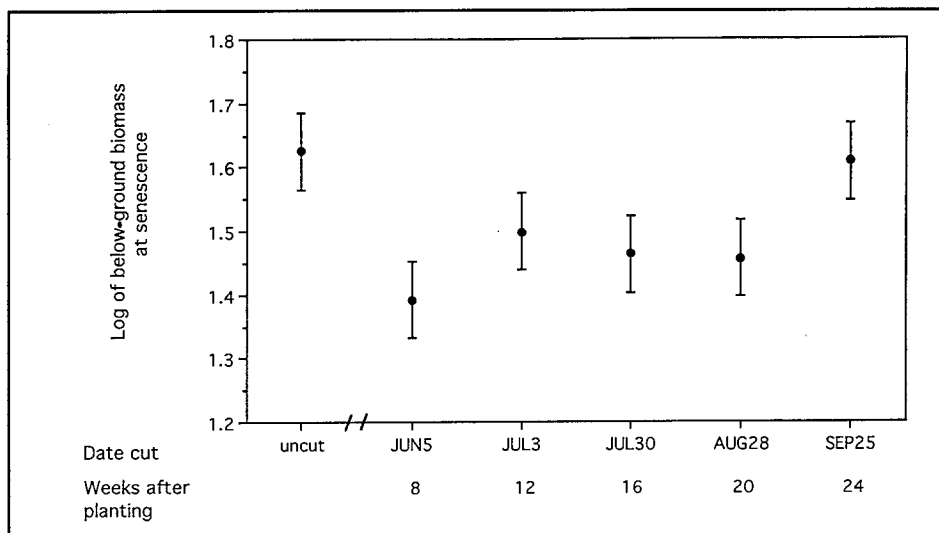


Figure 2. Belowground biomass at senescence of uncut controls and of plants cut once at different times during the growing season. Means are presented with Tukey's W confidence intervals ($\alpha = 0.05$).

that study was performed concurrently using rhizomes from the same collection.

Effects of Varying the Number of Cuts, Time of Season in Which Cutting Occurs, and Time Interval between Cuts

Belowground biomass varied significantly among cutting treatments in the second cutting experiment as well (ANOVA, $P < 0.001$). All cut plants had accumulated significantly less belowground biomass

than had uncut plants, and rhizome biomass at the end of the season was inversely related to the frequency of cutting (Figure 3). Uncut controls had 31.24 g of belowground biomass at the end of the growing season. Plants cut twice had accumulated significantly less belowground biomass (9.76 g) than plants cut once (20.01 g), and plants cut three times had the least belowground biomass (4.02 g). The linear regression of number of cuts on belowground biomass was highly significant ($r^2 = 0.75$, $P < 0.001$). The linear regression

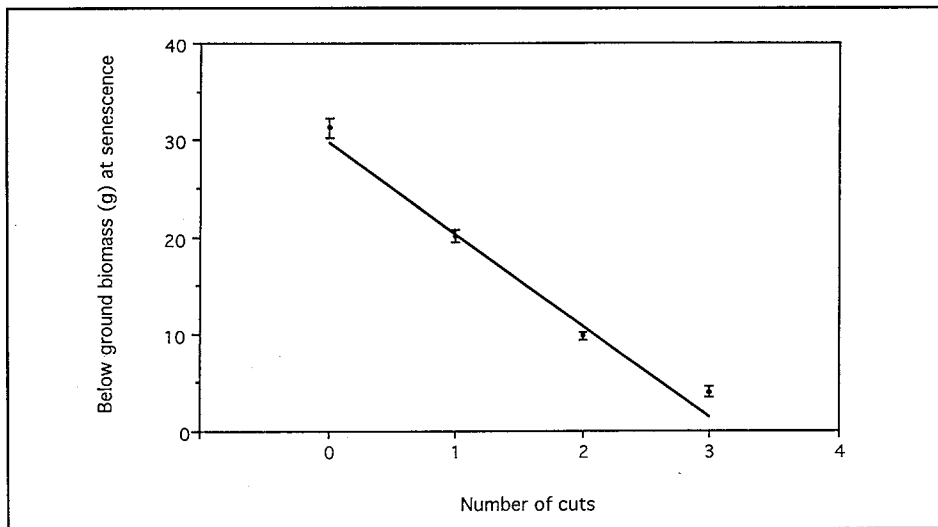


Figure 3. Belowground biomass at senescence as a function of the number of times that plants were cut during a single growing season. Means are presented with ± 1 SE.

(slope = -9.44, intercept = 29.68) predicts that at least four cuts are needed to cause a net depletion of belowground biomass over the growing season.

Among plants cut only once (in June, July, or August), there was no significant difference in belowground biomass at the end of the season regardless of the timing of the cuts. Similarly, there was no significant difference in the amount of belowground biomass among plants cut twice, in spite of differences in timing of cuts or the length of time between cuts (4 weeks versus 8 weeks). These results confirm the 1989 finding that the timing of cutting does not influence the amount of belowground biomass remaining at the end of the season.

DISCUSSION

Cutting pot-grown *F. japonica* plants at soil level reduces the accumulation of rhizome biomass. *Fallopia japonica* plants cut once by late August had less rhizome biomass at the end of the growing season than uncut plants. Cutting later in the season after allocation to aboveground growth had ceased was ineffective in reducing the accumulation of belowground reserves (Figure 1). The amount of rhizome biomass accumulated over the growing season was significantly less with each additional cut.

Predictions from a linear regression indicate that four cuts would be needed to cause a net reduction in rhizome biomass over the growing season. However, the relationship between number of cuts and belowground biomass may not remain linear as the number of cuts per season increases; more cuts may be needed than predicted from a straight-line regression. Preliminary field trials in a Washington, D.C., floodplain indicated that five cuts during a growing season caused considerable reduction in the vigor of a large stand of *F. japonica* but did not eliminate it (G. Sikora and P. Shaw, Rock Creek Park, Washington, D.C., pers. com.). Large field stands with more belowground reserves may use a smaller proportion of their reserves to resprout after cutting and thus may require more cutting treatments than small individuals grown in pots. In this study, plants in the 1989 cutting experiment, grown 1 month longer and therefore larger than those in the 1990 experiment, had more belowground biomass remaining after a single cut compared with their smaller counterparts from the 1990 experiment. Further studies in the field are needed to determine the effects of cutting on large established stands. In the wild, *F. japonica* stands can develop from as little as 7 g of rhizome (Child et al. 1992) and may take years to achieve full size. Optimally, control should be implemented

while plants are small. The plants used in this study were well developed (control plants flowered at the end of the season), and the findings of this study may be directly relevant to small populations in the wild.

Fallopia japonica reaches maximum height for the season within approximately 3 to 4 weeks of breaking dormancy (pers. obs.), relying on belowground reserves for growth. To prevent replenishment of belowground reserves, plants should be cut at least every 4 weeks throughout the growing season. The timing of cutting does not appear to be critical as long as it is done at least 7 weeks prior to senescence. More than 1 year of cutting may be needed to achieve control, and persistence is necessary.

Cutting alone will not eliminate *F. japonica* because the plant can regenerate once cutting is stopped, as occurs with bracken fern (*Pteridium aquilinum* L.) (Marrs et al. 1993). Cutting may be useful as an adjuvant treatment to reduce the overall vigor of *F. japonica* stands, thus increasing the efficacy of other treatments and reducing the use of herbicides in sensitive natural areas.

The successful reestablishment of native competitors is an important component of exotic species management (Thomas 1988). Nonselective herbicides target native species as well as exotic ones and thus their use is discouraged; but repeated cutting also can cause disturbance due to trampling. A combination of methods that minimizes adverse impacts on native species and habitat quality will probably be needed to eradicate *F. japonica*.

ACKNOWLEDGMENTS

This research was funded in part by two Grants-in-Aid of Research from the George Washington University Chapter of Sigma Xi. We extend our thanks to R. Mills for caring for the greenhouse stock, to O. Flaggel for his considerable assistance, and to R. Donaldson and E. Wells for lending equipment. We are also grateful for comments on the manuscript provided by N. Hartwig, P. Zedler, and anonymous reviewers.

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