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To cite this version:

Soraya Rouifed, Marylise Cottet, Margot de Battista, Yves-François Le Lay, Patrick Rateau, et al.. Inefficiency of cutting stems once during the vegetative growth of Fallopia spp.. Management of Biological Invasions, 2020, 11 (3), pp.399-405. 10.3391/mbi.2020.11.3.03 . hal-02972113

HAL Id: hal-02972113

https://univ-lyon1.hal.science/hal-02972113v1

Submitted on 24 Jun 2022

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Short Communication

Inefficiency of cutting stems once during the vegetative growth of *Fallopia* spp.

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Citation: Rouifed S, Cottet M, de Battista M, Le Lay Y-F, Rateau P, Rivière-Honegger A, Piola F (2020) Inefficiency of cutting stems once during the vegetative growth of *Fallopia* spp. *Management of Biological Invasions* 11(3): 399–405, https://doi.org/10.3391/mbi.2020.11.3.03

Received: 27 September 2019
Accepted: 14 February 2020
Published: 17 May 2020

Handling editor: Amy Yackel
Thematic editor: Catherine Jarnevich

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Abstract

The management of some invasive plant species is difficult because species can exhibit high productivity despite control measures. Inefficient control methods may even produce unwanted side effects. We conducted an experimental study on *Fallopia* spp., a major invasive plant in Europe. We tested the effects of two different stem-cutting frequencies on the aboveground and belowground traits of several genotypes in a greenhouse experiment against control plants (no cuts). Plants receiving one cut per month for a total of 4 cuts experienced 30% mortality of the individuals, surviving plants had greatly reduced values of the measured traits, especially for biomass and height. In contrast, plants in the treatment group, consisting of a single cut in five months, were eventually able to compensate for the loss of aboveground parts despite reduced length and biomass of the rhizome. Our results indicate that minimal mechanical intervention has limited effects on *Fallopia* spp. During the vegetative season, managers can increase control efficacy through regular cutting rather than a one-time intervention for these species.

Key words: Japanese knotweed *s.l.*, mechanical control, growth trait, clonal species, invasive plants

Introduction

Herbicide use in invasive plants management has declined because of concerns over environmental and health impacts and its restricted use in areas near water. Mechanical control methods are a viable alternative but have shown variable success for clonal species with high regeneration ability because physical disturbances can also facilitate invasion, leading to management dilemmas (see the work of Jia et al. 2009 on *Alternanthera philoxeroides*). Therefore, to make management recommendations, the first step is to experimentally assess the response of the considered species to physical disturbance.

Invasive species of the genus *Fallopia* are herbaceous perennial species known to be difficult to control (Rouifed et al. 2011; Delbart et al. 2012;

Schiffleithner and Essl 2016). They quickly produce aboveground and belowground biomass with high stem and rhizome regeneration abilities (Bímová et al. 2003). *Fallopia japonica* (Houtt.) Ronse Decraene, 1988, *Fallopia sachalinensis* (F. Schmidt ex Maxim.) Ronse Decraene, 1988, and the hybrid *Fallopia* × *bohemica* (Chrtek and Chrtkova) Bailey, 1989, are widespread invaders in Europe in riparian habitats and disturbed areas (Bailey and Wisskirchen 2004). *Fallopia* taxa showed different invasiveness, with *F.* × *bohemica* often performing better than the parent species (Parepa et al. 2014). In a field experiment, the height and stem density of *F. japonica* were not affected by repeated cuts (monthly cuts, Delbart et al. 2012). One single-cut treatment even increased stem density by 50% (Delbart et al. 2012). However, site characteristics (two sites per treatment) and plant characteristics (different initial surface area of the populations and different rhizome mass) could have influenced the results of the field experiments. Moreover, as different *Fallopia* taxa showed contrasting responses to stem cutting, with *F. japonica* being less tolerant (Rouifed et al. 2011), the efficacy of these methods of mechanical control must also be assessed for *F.* × *bohemica* and *F. sachalinensis*.

Here, we conducted an experiment in controlled conditions testing the effects of different frequencies of stem cutting on standardized clones of several populations of the three taxa. We hypothesized that 1) compared to control and single-cut treatments, repeated cuts would reduce aboveground and belowground mass, as well as stem height and density and 2) *F. japonica* would be more affected than the other taxa by the cutting treatments, based on a previous study (Rouifed et al. 2011).

Materials and methods

In February 2011, we collected plants from 8 populations in the Rhône-Alpes region: 3 *F. japonica* (municipalities of Montrond-les-bains, Etrat and Chambon-Feugerolles), 3 *F.* × *bohemica* (municipalities of Veauchette, St Etienne-le-Molard and Villeurbanne), and 2 *F. sachalinensis* (municipalities of Noiretable and Vienne). We cleaned the rhizomes of these 8 populations and cut them into fragments (20 g ± 2 g). We planted 15 fragments per genotype in 120 L containers filled with peat compost (FAVORIT). The plants were randomly placed in a greenhouse. The experiment lasted for 20 weeks (approximately the length of a growing season).

We applied 3 different treatments consisting of different frequencies of cutting of the plants: (1) a single-cut treatment (a historically-used method by French managers, Rouifed *personal observation*) implemented at ten weeks after the beginning of the experiment; (2) a four-cut treatment, one cut every four weeks; and (3) a control treatment (no stems were cut). Each treatment was applied to 5 randomly chosen plants per population (n = 40 plants/treatment group; 8 populations × 5 plants per group). When the plants

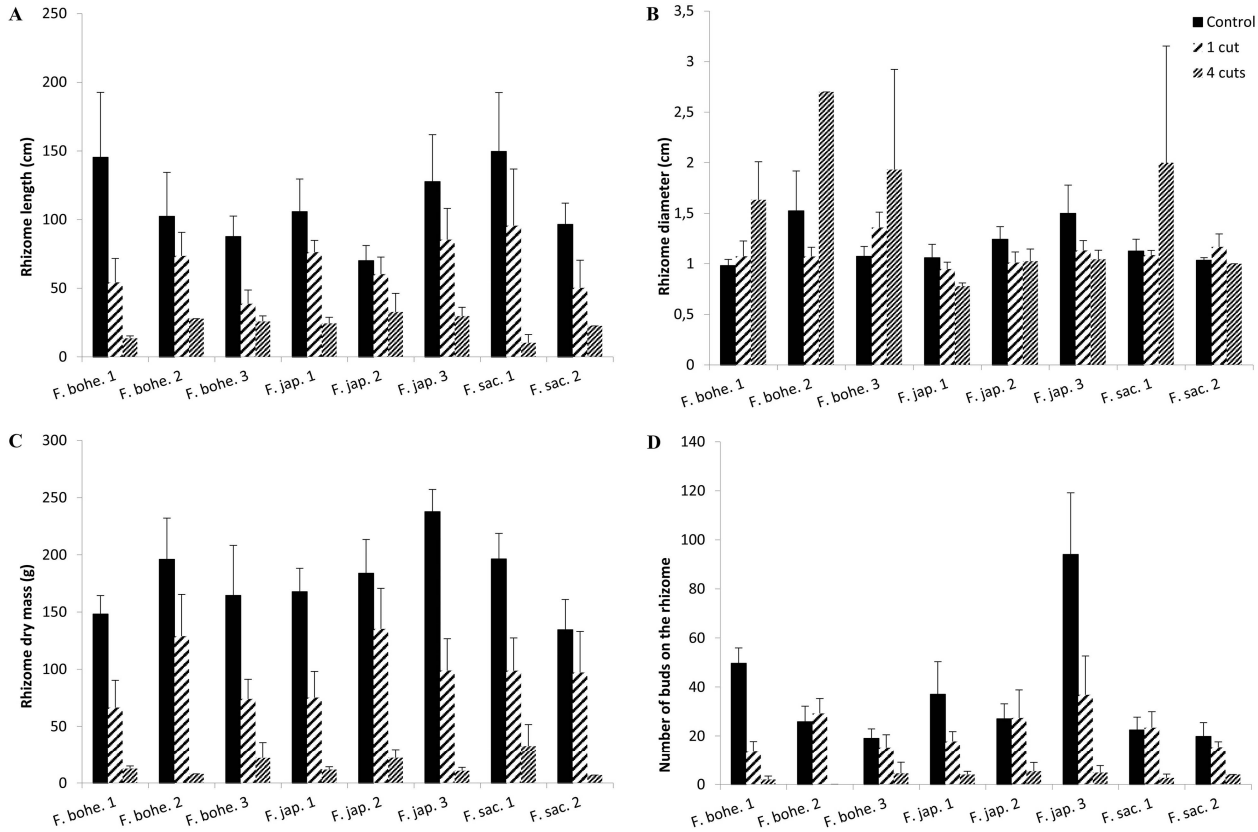

Figure 1. Mean and standard error of the belowground traits of plants (rhizome length (A), rhizome diameter (B), rhizome dry mass (C), and number of rhizome buds (D)) measured in control, single-cut, and four-cut treatment groups for the eight populations.

were cut, the entire aboveground structure was removed, oven-dried (at 60 °C for 48 h) and weighed.

At the end of the experiment, we counted the dead plants (no aboveground parts and decayed rhizome). For the surviving plants, we measured the rhizome length (cm), rhizome diameter (cm), number of buds on the rhizome, belowground dry weight (gr), number of stems, maximum stem height (cm), and final dry weight of the leaves (gr). The total aboveground dry weight was calculated as the sum of the weights of the clipped aboveground parts and the final aboveground harvest.

The effect of the two factors (treatment [control, single-cut, or four-cut] and population [8 levels]) and their interaction on measured variables were analysed with R software (R Core Team 2012). Because of heteroscedasticity in the data, we used "generalized least square" models (gls) from the nlme package, to address unequal variances between factors.

Results

A total of 30% of the plants in the four-cut treatment group (6 individuals of the *F.* × *bohemica* and 6 individuals of the *F. sachalinensis* genotypes) were dead at the end of the experiment, whereas all the plants in the control and single-cut treatments survived. For each measured variable except rhizome diameter, the results in the four-cut treatment were lower than the results for the control and the single-cut treatments (Figures 1 and 2).

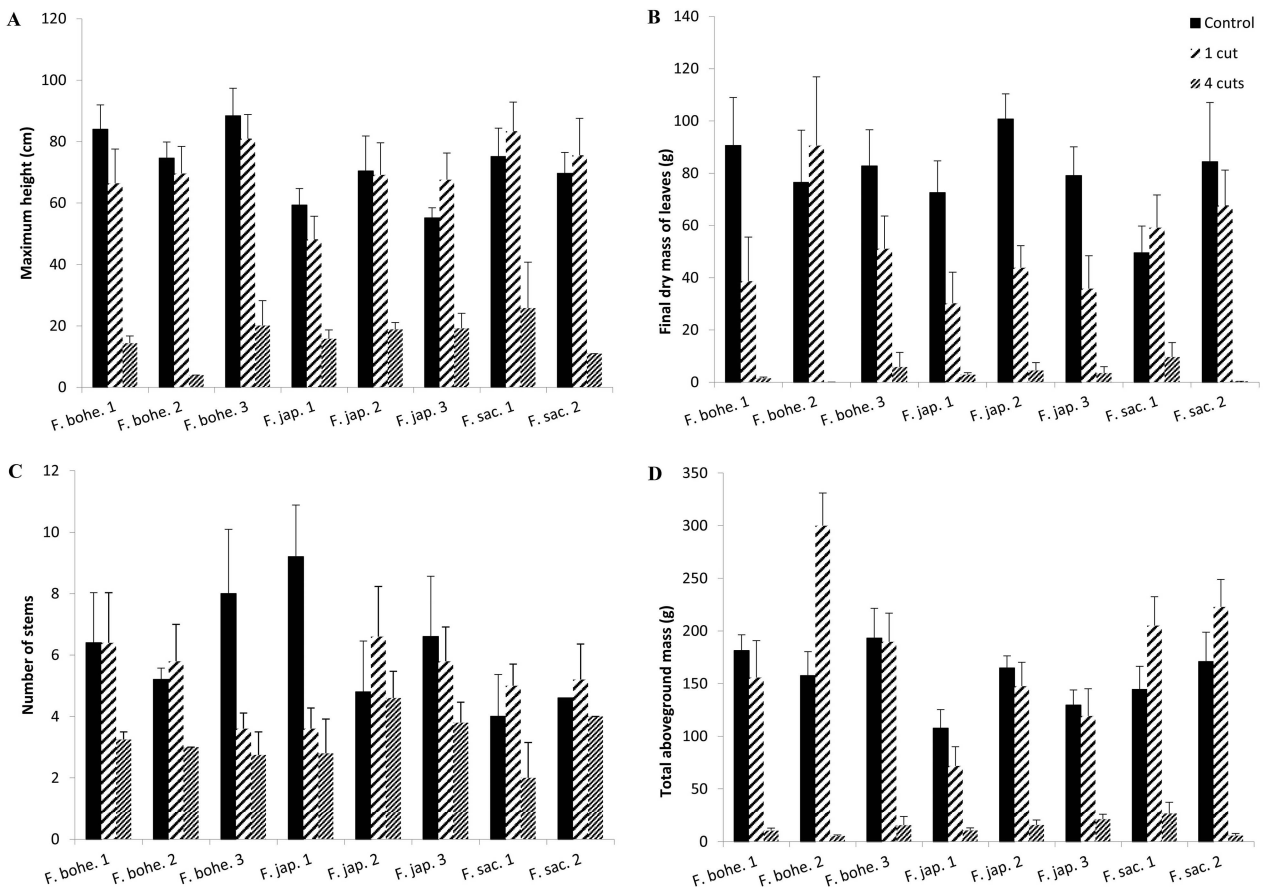

Figure 2. Mean and standard error of the aboveground traits of plants (maximum height (A), final dry mass of leaves (B), number of stems (C), and total aboveground mass (D)) measured in control, single-cut, and four-cut treatment groups for the eight populations.

Rhizome length and mass showed similar responses across treatment groups. These variables were lower for both the single-cut (−39.6% for rhizome length and −48.0% for rhizome mass) and in four-cut (−77.5% for rhizome length and −90.6% for rhizome mass) treatments compared to the control plants (F = 43.34, p < 0.001 for rhizome length and F = 191.50, p < 0.001 for rhizome mass, Figure 1A, C). We found no differences between the populations (F = 0.97, p = 0.461 for rhizome length and F = 2.08, p = 0.055 for rhizome mass). The four-cut treatment reduced the number of buds on the rhizome in one population of *F. japonica* (−95% compared to control plants) and in one population of *F.* × *bohemica* (−96%) where the number of buds in the single-cut plants was also reduced by 73% (interaction between treatment and populations, F = 2.66, p = 0.003, Figure 1D). The rhizome diameter was not affected by the treatment (F = 1.21, p = 0.304) and was not different between populations (F = 1.50, p = 0.130).

Plant height differed depending on species (F = 4.85, p < 0.001). The 3 populations of *F. japonica* were the shortest, and the populations of *F. sachalinensis* were the tallest. A single cut did not affect the final height of the plants whereas four cuts reduced the height by 75.2% (F = 125.42, p < 0.001, Figure 2A). The stem number was not affected by the lowest frequency of the treatment, but was reduced by 45.6% by four cuts (F = 12.52,

$p \leq 0.001$) and did not differ between populations ($F = 0.86$, $p = 0.542$, Figure 2C). The final leaf mass was lower in the single-cut (−34.4%) and four-cut treatment groups (−94.9%) than in the control plants ($F = 147.67$, $p < 0.001$, Figure 2B). One population of *F.* × *bohemica* had the highest final leaf mass, and one population of *F. japonica* the lowest ($F = 2.17$, $p = 0.045$).

Across all populations, whereas plants in the four-cut treatment decreased total aboveground weight (final mass + cut mass) by 91% (F = 309.98, $p < 0.001$), there were no differences between the plants in control and single-cut groups (Figure 2D). However, in one population of *F.* × *bohemica,* the total aboveground weight was higher (+90.5%) for plants in the single-cut treatment than for control plants, showing a potential stimulating effect (interaction between treatment and populations, $F = 5.76$, $p < 0.001$).

Discussion

Similar to many invasive species, *Fallopia* is known to be difficult to control (Delbart et al. 2012). Mechanical methods are generally employed to reduce the aboveground or belowground biomass of patches of various sizes. Here, in our experiment, in accordance with our first hypothesis, we showed that four cuts in the vegetative season influenced all measured traits. In the field, because of the higher biomass of the rhizome that would reduce the mortality induced by the cutting, regular cutting should probably be applied for several years before obtaining results. The single-cut treatment also reduced the rhizome length and dry mass compared to the untreated individuals, but the reduction is probably insufficient to effectively control the growth of a patch in the field. More importantly, a one-time cut neither affected the height nor the number of the stems of individuals from all species but instead reduced leaf biomass. Even if fewer or smaller leaves reduced the ability of the species to harvest light, compensating for height (*i.e.,* the treated individuals reached the same height as the controls) would help the species restore their competitive ability for light. A similar response to a low level of aboveground damage has also been shown in other high performing invasive species, for example in *Eichhornia crassipes*, which showed compensatory growth at low levels of defoliation (Soti and Volin 2010).

Contrary to our second hypothesis, *F. japonica* seemed to be more tolerant to the four-cut treatment as *F. sachalinensis* and *F.* × *bohemica* died. Globally, in response to the single-cut treatment, few differences were found between the populations. Nevertheless, unexpectedly, the single-cut treatment probably stimulated regeneration in one population of *F.* × *bohemica* (higher number of rhizome buds than in the control). Moreover, the results of total aboveground weight indicated that at least one population of *F.* × *bohemica* was able to enhance its growth in response to cutting,

which could be a possible mechanism leading to an overcompensation effect. These contrasting responses between the populations of *F.* × *bohemica* might be explained by the high genetic diversity of the taxon. As we tested only a small number of the existing genotypes, it is not possible to predict the frequency of the individuals who can compensate for cutting, or whether even higher performing genotypes are widespread. The high regeneration abilities of *F.* × *bohemica* (Bímová et al. 2003) and its response to disturbance, in particular, whether its growth can be stimulated by physical disturbance, are probably involved in its invasive success.

Compensation or overcompensation effects have to be considered in management plans (Soti and Volin 2010) because they might reduce the efficiency of management, and possibly increase the impacts of the species by stimulating aboveground growth, especially in *F.* × *bohemica*. If an intensive mechanical control is not feasible at invaded sites, then avoiding any intervention would be warranted. Thus, management goals should include the prevention of spread and the reduction of impacts while minimizing non-target effects (Larson et al. 2011). For example, deleterious non-target effects could result from intervention at an invaded site disturbing or damaging native species and the transportation of the removed vegetation accidentally spreading invasive propagules. Managers must therefore consider the ecological trade-offs (ecological costs and benefits of the techniques used; Skurski et al. 2013) and prescribe management plans based on well-defined objectives.

Acknowledgements

The authors would like to thank two anonymous reviewers and the handling editor for the improvement of the manuscript, as well as C. Bengasini, M.R. Viricel, D. Debouchages, F. Vallier and M. Demarquet for their technical help.

Funding declaration

The experiment benefited from the "Serres and chambres climatiques" platform of the FR BioenviS of Université Lyon 1. We are grateful to the regional water agency (in partnership with the LTER-ZABR) and the IngECOTech program (INEE-CNRS) for funding and supporting this research.

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