

Two-thirds of the seeds of invasive Himalayan balsam (*Impatiens glandulifera*) grow after overwintering at a western Finnish site

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Himalayan balsam (*Impatiens glandulifera*) is an invasive plant species in much of Europe. It is not well known how easily its seeds survive the winter and grow into seedlings, and eradication efforts typically focus on destroying plants in early summer before they produce seeds. I monitored both ripe and unripe balsam seeds spread onto the ground at a site with a balsam outbreak in western Finland. About two-thirds of the ripe seeds developed into seedlings the following year, as did a third of unripe seeds. Ripe seeds grew even better on disturbed ground with exposed soil. Each balsam plant thus has the potential to produce hundreds of viable offspring. For eradication efforts, the establishment rates observed at this site (1/3 unripe seeds and 2/3 ripe seeds) suggest that destroying sparsely growing balsam plants whose seeds are not yet ripe can be worthwhile and will considerably decrease the number of seedlings in the following year.

Introduction

Himalayan balsam (*Impatiens glandulifera* Royle) is an originally Himalayan plant species that has become invasive in large parts of the world (Perrins *et al.* 1993). It was introduced to Finland in the 19th century (<https://vieraslajit.fi/lajit/MX.39158>) and remained uncommon until the 1990s (Huusela-Veistola *et al.* 2019: 53–76). During recent decades its numbers and distribution have increased markedly in Finland, and it is now widespread throughout all but the northernmost parts of the country (Huusela-Veistola *et al.* 2019: 53–76; e.g. 4534 observations in the Finnish Biodiversity Information Facility in 2024: <http://tun.fi/HBF.108069>).

Due to its invasiveness, the cultivation and distribution of Himalayan balsam have been banned throughout the European Union (http://data.europa.eu/eli/reg_impl/2016/1141/2024-08-02). Balsam often forms dense stands, especially along riversides and other moist habitats, displacing native vegetation (Chittka & Schürkens 2001, Huusela-Veistola *et al.* 2019: 53–76). They also contribute to erosion because they only form shallow, weak root systems, which die off when the annual plants die in autumn (Huusela-Veistola *et al.* 2019: 53–76). Plants start producing seeds in late summer and each plant produces hundreds or even more than a thousand seeds during the season (Perrins *et al.* 1993). The seeds, although small and relatively delicate

(Juola 2021), are more than able to replace and expand a stand the following year.

Little is known about how well balsam seeds survive and produce seedlings in their invasive range, other than the fact that many do. Almost all seeds in a Czech study germinated in the following year (Skálová *et al.* 2019). These were, however, buried rather than dispersed on the soil surface, as would occur naturally. Almost no seeds sown at a semi-natural site near York, England survived, but 40% of the seeds sown in a garden grew into seedlings (Perrins *et al.* 1993). The sowing method was not specified, and sowing was carried out in February instead of in autumn. Both experiments used mature, ripe seeds. Unripe seeds, which can be released in large numbers during eradication of balsam stands (pers. obs.), seem not to have been studied at all.

Himalayan balsam is mainly controlled by pulling the plants out by hand or cutting them with a trimmer in early summer before seed development (<https://vieraslajit.fi/lajit/MX.39158>). In principle, this could be done later in the season too, but this would release seeds. Both national guidelines (<https://vieraslajit.fi/lajit/MX.39158>) and my personal observations suggest that eradication efforts are usually discontinued once the first seeds appear. This is due to concern that released seeds would establish in the following year, rendering control efforts ineffective.

In this study, I mimicked how seeds are released, both naturally and during eradication, by spreading both ripe and unripe seeds onto the ground at a site in western Finland. I then recorded how many grew into seedlings in the following year. My aim was to get data on the seed establishment of Himalayan balsam in Finnish conditions and also draw practical conclusions for eradication efforts of this invasive species.

Material and methods

I collected seeds on 19 August 2024 from balsam plants in a wooded area near houses (63.6260° N, 22.8825° E) in Kállby village, Pietarsaari, western Finland. The site is typical of the moist, human-disturbed habitats in which many invasive balsam outbreaks occur in the region. It has

formerly been used to collect clay for bricks, and contains a mix of mature trees including alder (*Alnus incana*), birch (*Betula* sp.), aspen (*Populus tremula*), spruce (*Picea abies*) and pine (*Pinus sylvestris*); the dense shrubby undergrowth included a large, dense stand of balsam plants.

I collected a large number of unripe and ripe balsam seeds (Fig. 1A). Unripe seeds were white, soft, and were released from pods when touched, but did not fly far. Seeds that were too unripe to be easily released were not collected. Ripe seeds were black, dry, and flew out of the pods at the slightest touch. A few hours after collection, I placed a total of 320 ripe seeds and 160 unripe seeds on the ground approximately 10–20 metres from the nearest balsam plants. I sprinkled the seeds onto the ground to mimic natural dispersal from the pods.

I placed seeds within an 80 × 80 cm frame that was divided into 16 squares (Fig. 1B). The squares were assigned to four different treatments, with four squares per treatment:

- 1) Ripe seeds on disturbed ground. I scratched the ground, exposing the soil, and sprinkled 40 ripe seeds in each square.
- 2) Ripe seeds. I sprinkled 40 ripe seeds in each square.
- 3) Unripe seeds. I sprinkled 40 unripe seeds in each square.
- 4) Blank. Control squares into which I did not add any seeds.

In practice, some seeds bounced out of their square when sprinkling. I interpreted some seedlings that grew just outside the frame as belonging to the nearest square. Also, some seeds accidentally fell into square 14, a control square, when sprinkling in square 15. I interpreted the five seedlings that grew in square 14 as belonging to square 15 (*see data in* <https://doi.org/10.5281/zenodo.15616262>).

I checked the frame for seedlings every one to four weeks in May–September 2025, and counted and removed them whenever they appeared. In practice, almost all seedlings appeared in May–June, although I removed a few larger seedlings, which had presumably escaped observation among other plants, in early July (<https://doi.org/10.5281/zenodo.15616262>). To avoid unintentionally spreading the species,



Fig. 1. — **A:** Collected balsam seeds. Unripe white seeds on left, ripe black seeds on right. The pictures include a few seeds that are in the wrong box or are intermediate (brown), which I did not use. — **B:** Frame with 16-square grid into which I added seeds. U = unripe seeds, R = ripe seeds, R+ = ripe seeds on disturbed ground, - = control without seeds.

in the unlikely event that some seeds remain in the soil seed bank, I left the frame in place and will monitor it in summer 2026.

For each treatment, I calculated the mean and standard error (SE) of the number of seedlings that appeared in summer 2025. I did not need to account for naturally occurring balsam, since only one seedling appeared in a control square, and no naturally occurring balsam seedlings appeared within one metre of the frame. I interpreted the one seedling in a control square as having rolled there during sowing of the seeds.

I calculated if different treatments differed significantly in seedling numbers with Fisher's

exact test (Fisher 1934: 99–101). Fisher's test is particularly well suited to this low sample size, with data from just four treatments in one plot.

I did all analyses in R v. 4.2.1 (<https://www.R-project.org/>). The analyses and data are available at <https://doi.org/10.5281/zenodo.15616262>.

Results

With 40 seeds sown per square, squares with ripe seeds on disturbed ground produced 30.5 seedlings (SE = 1.7), squares with ripe seeds 24.8 seedlings (SE = 2.1), and squares with unripe

seeds 15.3 seedlings (SE = 2.0) (Fig. 2). These translate to 76%, 62% and 38% of the seeds, respectively. The four control squares produced only one seedling in total.

Seedling numbers differed significantly between all four treatments (Fisher's exact test, highest pairwise $p = 0.008$).

Discussion

Approximately two-thirds of Himalayan balsam seeds can be expected to produce seedlings at this study site, provided that they fall onto ground that is not overcrowded by other balsam seeds. This is a substantial amount, given that individual balsam plants produce hundreds or even more than a thousand seeds (Perrins *et al.* 1993). It is higher than the 40% of seeds that established in an English garden (Perrins *et al.* 1993), but less than the 95% of planted seeds that germinated in Czechia (Skálová *et al.* 2019).

Disturbance that exposed the soil increased seedling establishment to three quarters of the seeds. This, and the high germination rate observed in Czechia when seeds are buried (Skálová *et al.* 2019), suggests that many seeds failed to establish because they landed on leaves or other unsuitable surface litter. The structure of the soil surface thus likely has a strong effect on seed establishment of balsam.

Overall, these results show that a single balsam plant has the potential to produce hundreds of viable offspring in the following year. Solitary plants in suitable terrain are likely to do so. In dense stands, where not all seedlings can establish because of overcrowding, the ground is likely to become saturated with seedlings.

These results suggest two future topics of study. One is to determine how different environmental conditions at different sites affect the proportion of balsam seeds that develop into seedlings. Shade, in particular, is expected to reduce this proportion from the two-thirds observed here, as the study site was typical of areas overrun by invasive balsam in having little shade early in the summer when growth begins. The second, related, topic is to determine whether the hundreds of viable seeds per plant that fail to establish in overcrowded stands simply die

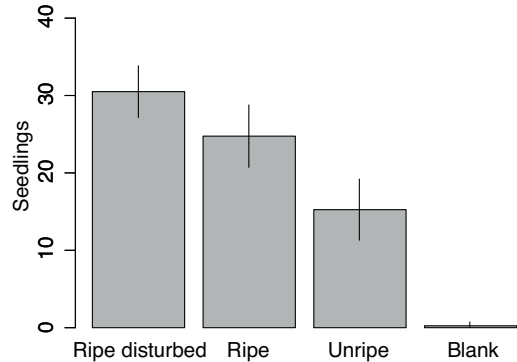


Fig. 2. Average number of seeds that grew into seedlings in each study square for the following treatments: ripe seeds sown on disturbed ground, ripe seeds, unripe seeds and control squares without seeds. Error bars show 95% confidence intervals.

or form a seed bank. The results of Skálová *et al.* (2019) suggest the former, but are based on somewhat unnaturally burying of seeds. If a seed bank does form, the environmental conditions determining whether seeds establish in the following year or persist in the seed bank warrant investigation, as does seed longevity.

For the planning of eradication efforts, these results suggest a general rule of thumb: one-third of unripe and two-thirds of ripe dropped seeds can be expected to establish the following year. This rule is approximate, and absolute rates may differ under other environmental conditions. Whether control of a balsam stand is worthwhile depends on context. The older a plant becomes, the more seeds it has time to produce (Perrins *et al.* 1993: fig. 5), and the number of seeds released depends on their maturity and the control method used. For example, trimming a dense stand of balsam after moderate numbers of unripe seeds have appeared will often not be effective. Many seeds are likely to be released, and, despite being unripe, enough may establish in the following year to saturate the ground. However, trimming the edge of such a stand may be worthwhile, as this would decrease the number of seeds that spread the stand outwards. Likewise, sparsely distributed plants may be worth trimming or removing by hand even late in the season if not all seeds are ripe, if the resulting decrease in the number of balsams growing next year is deemed worth the effort.

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