



Life after fire: smoke and ash as germination cues in ericads, herbs and graminoids of northern heathlands

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Introduction: Fire is an important disturbance factor in many terrestrial ecosystems, one of which is heathlands. Heathlands are periodically exposed to natural or anthropogenic fires, the latter of which are used as a management strategy to maintain heaths. As a result, heathland species are likely to either tolerate, or be facilitated by fire or its by-products. Previous studies have documented the efficacy of smoke, charcoal, ash and heat in promoting germination in a wide range of species and systems, but relatively little has been done in northern European heathlands. In this study we aim to investigate the germination responses of important functional groups in the heathland system, namely ericads, herbs and graminoids, to ash- and smoke treatments in a soil seed bank study.

Study site: The island of Lygra at 60°42'N and 5°5'E, Western Norway.

Methods: We studied smoke and ash effects experimentally by investigating the effects of aqueous smoke solution, burnt heather biomass (ash) and a combination of the two treatments on the germination of graminoids, herbs and ericads (*Calluna vulgaris* and *Erica tetralix*). Ash was used to mimic the total effect, excluding heat, that a management fire would have, and smoke solution was used to test for the specific effect of the smoke molecule, karrikinolide. All treatments were applied to soil samples taken from old heath stands (burned 28 years ago), as well as heath stands that were burnt the previous year.

Predictions:

- If germination in heathland seed banks is regulated by fire cues, there should be increased germination in seed banks taken from old heath in comparison with seed banks taken from newly burnt heath, which have been exposed to the same cues *in situ* more recently.
- If the added burnt heather biomass does not have an effect above and beyond the smoke solution, this suggests that the smoke cue is the most important one.

Results:

- Both ericads and graminoids respond mostly positively to fire cues, whereas herbs generally do not
- Responses are stronger in the older heath samples when compared with the new.
- Smoke seems to be a more effective cue than ash across all species groups.
- The combined treatment shows that the effects of ash and smoke are not additive, but rather that they replace each other to achieve higher germination rates.

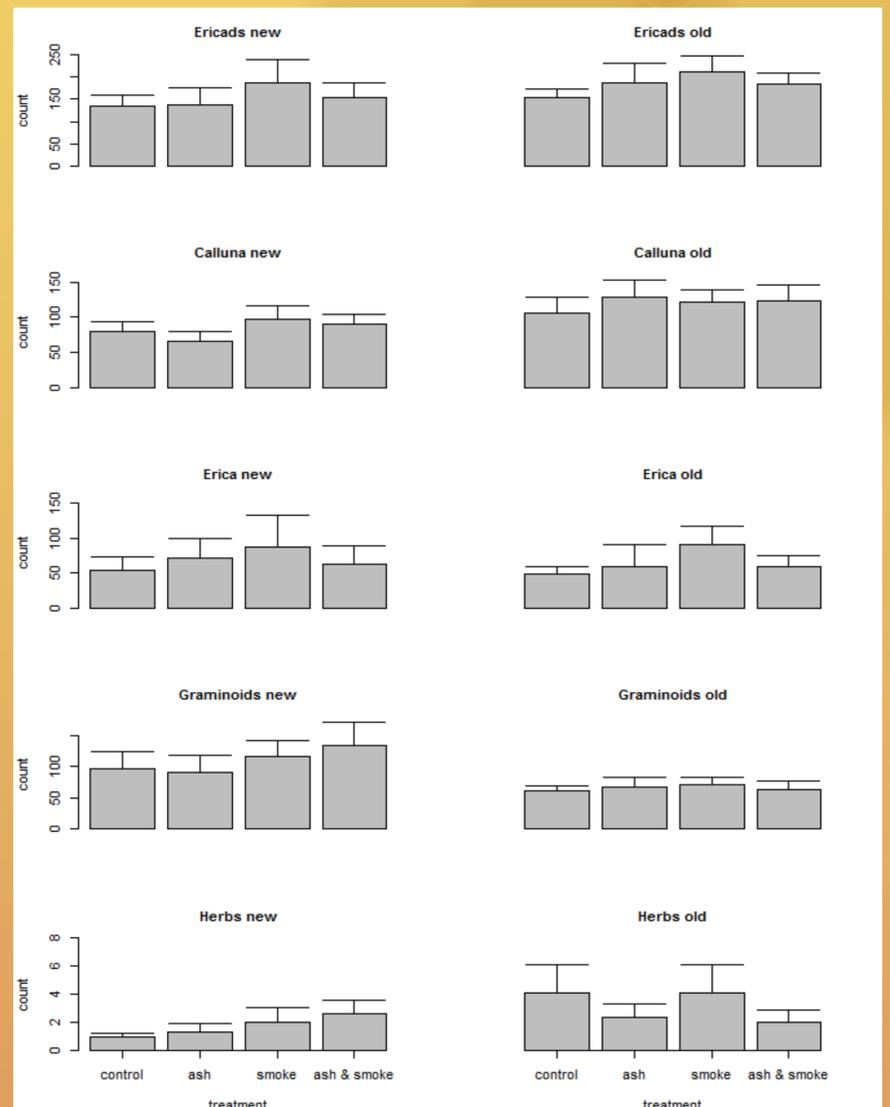


Figure 1: Mean seed bank germination counts with standard deviations in all species groups for the four different treatments; control, ash, smoke, and smoke and ash combined. "New" and "Old" refer to the age of the soil seed banks which were burnt in the previous year and 28 years ago, respectively.



Table 1: Estimates and *p*-values for germination counts from soil seed banks of each of the functional groups responses to smoke and ash, and the ash:smoke interaction, as predicted by a linear mixed effects model with a poisson family distribution. Values refer to samples that were burnt the previous year (new), and samples that were burnt 28 years ago (old). Significance codes: 0= "****", 0.001= "***", 0.01= "**", 0.05= "."

	New				Old			
	Intercept	ash	smoke	ash:smoke	Intercept	ash	smoke	ash:smoke
Ericaceous	4.63 ***	0.03	0.19 ***	-0.10 .	4.90 ***	0.25 ***	0.38 ***	-0.41 ***
Calluna	4.22 ***	-0.18 ***	0.01	0.21 **	4.53 ***	0.18 ***	0.17 ***	-0.16 **
Erica	3.14 ***	0.28 ***	0.41 ***	-0.82 ***	3.22 ***	0.39 ***	0.74 ***	-0.48 ***
Graminoids	4.06 ***	-0.06	-0.10 *	0.31 ***	3.95 ***	0.13 *	0.20 ***	-0.25 **
Herbs	-0.23	0.37	0.75 .	-0.04	0.21	-0.55 *	0.10	-0.17

Implications for Management: This study found that germination is particularly promoted by fire cues when the time since the last burning is long, further supporting the necessity for rotational burning within heathlands. The findings of this study imply that within this anthropogenic system, it is not only *Calluna vulgaris* that benefits from fire, but rather a large range of species. The prevalence of favourable responses to fire cues across species groups re-establishes the importance of burning as a central part of heathland management.

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