Impacts of gorse seed feeding biocontrol agents

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Hypothesis

Are current levels of seed predation caused by biocontrol agents sufficient to reduce gorse cover on a landscape scale?

Aims

- Complete a detailed assessment of seed production at two sites by measuring:
    - Seed predation
    - Seed fall
    - Seed banks
- Relate these data to a landscape scale model on gorse cover published in 2001 by Rees & Hill.

Two sites - Palmerston North and Christchurch

Age mean = 9.7 years, Altitude = 140 m

Age mean = 6.5 years, Altitude = 450 m

Methods

Used a combination of empirical data and modelling

10 shoots were tagged on each of 15 plants per site…

… and green pods marked to measure seed production.

Pods were collected when mature to assess seed loss due to predation.

Gorse seed feeding biocontrol agents

Gorse seed weevil

1931

Gorse pod moth

1989

Seed fall was measured in seed trays and seed banks estimated from soil cores.

Modelling paper by Rees and Hill (2001) predicts changes to landscape scale gorse cover under various seed reduction and management scenarios.

Journal of Applied Ecology 2001
38, 364–377

Large-scale disturbances, biological control and the dynamics of gorse populations

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Summary

1. Simulation and analytical models were developed for gorse *Ulex europaeus*. The simulation model incorporated spatially local density-dependent competition, disturbance, asymmetric competition between seedlings and established plants, a seed bank, local seed dispersal, an age structured established plant population, and temporal variation in the probability of disturbance. The analytical models were simple approximations of the simulation.

2. The models extended our previously published model for Scotch broom *Cytisus scoparius* to include large-scale disturbances and possible management options, such as the use of fire, herbicides and oversowing with perennial grasses. Fire was assumed to influence established plant mortality, seed survival in the seed bank, and the probability of germination.

3. We reviewed published data on the demography of gorse in New Zealand, the current management techniques, and the ongoing biological control programme.

4. Over a wide range of biologically reasonable parameter values, the analytical models accurately predicted the outcome of the simulations. The analytical models worked well, providing gorse occupied a high proportion of the available sites and large-scale disturbances did not occur too frequently.

5. The potential impact of seed-feeding biological control agents on gorse abundance was assessed, using the models, for several environmental and management scenarios. In particular, we explored how large-scale disturbance, such as fire and herbicide application, influences the outcome of biological control.

6. The success of a biological control programme was found to depend critically on the frequency and intensity of disturbance, whether disturbed sites became suitable for recruitment, and the effects of disturbance on germination and seed mortality.

7. The models highlight the need to manage recruitment opportunities carefully in order to maximize the effect of biological control agents. The models also indicate that details of plant population biology can have a profound effect on the success of any management strategy.

Key-words: environmental weeds, fire, integrated management, spatial modelling.

Journal of Applied Ecology (2001) **38**, 364–377

Introduction

Gorse *Ulex europaeus* L. Fabaceae is native to Europe but is most common on the western European seaboard from northern France to Portugal (Tutin *et al.* 1968). Gorse is a spiny shrub that is characteristically associated with heathland vegetation in Europe, but commonly invades neglected land and forests. It has become naturalized in many temperate countries around the world, and is regarded as a serious weed in New Zealand, Chile, Hawaii, North America and Australia (Richardson & Hill 1998). Gorse was recognized as an important weed in New Zealand as early as 1859 (Thomson 1922) and is now present on at least 3·5% of New Zealand's land area (Thomson 1922).

Gorse readily invades disturbed ground and can form dense impenetrable thickets. It can suppress plantation forests, exclude grazing animals from pastures, and increase the risk of fire in native habitats and urban areas. If left undisturbed for 20–30 years, gorse can be replaced by longer-lived plant species (Wilson 1994) but fire or other major disturbance often rejuvenates

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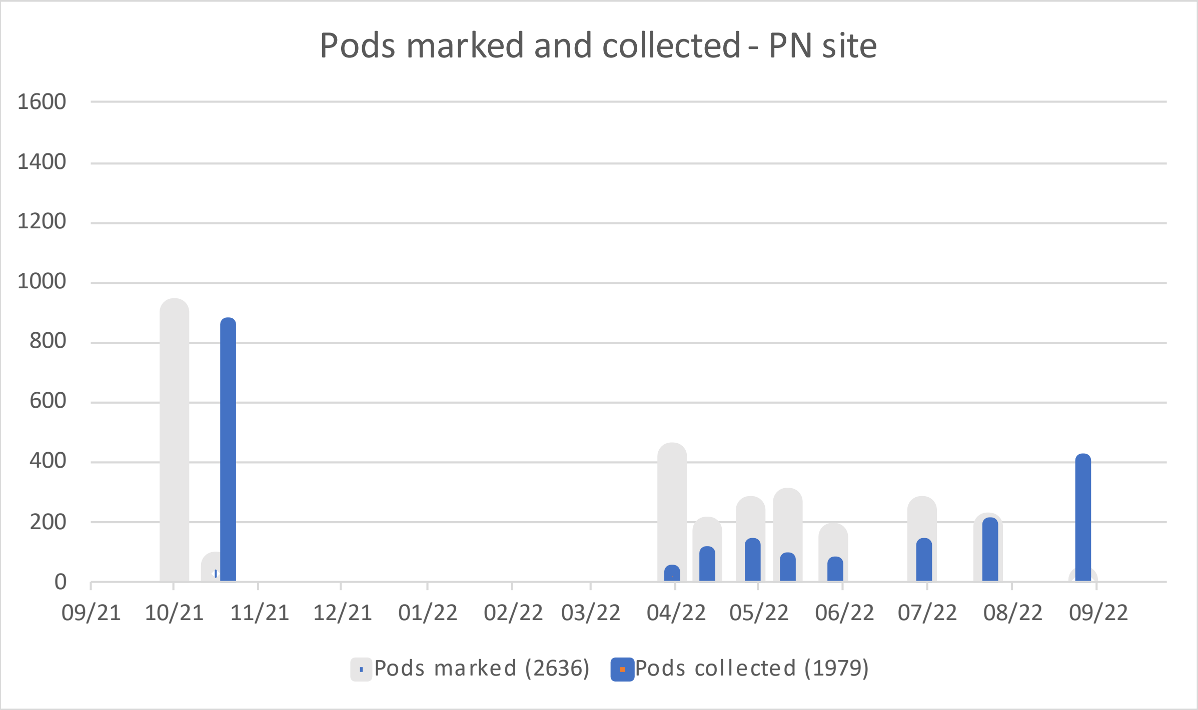
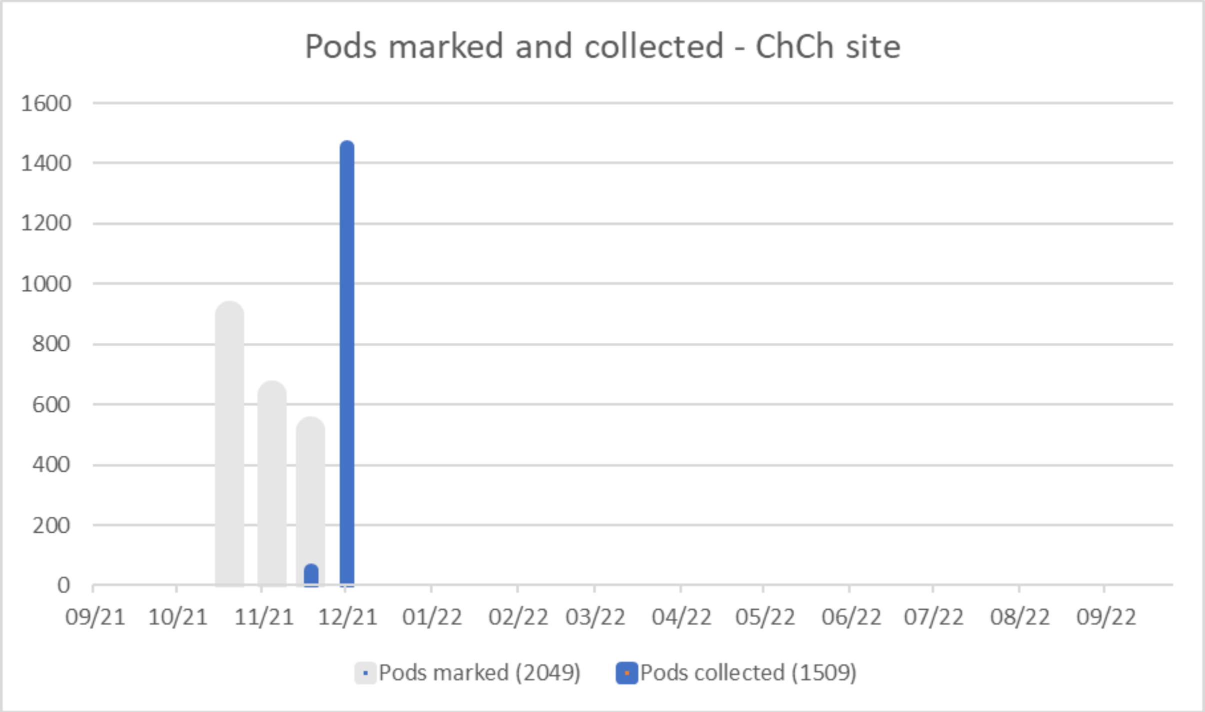
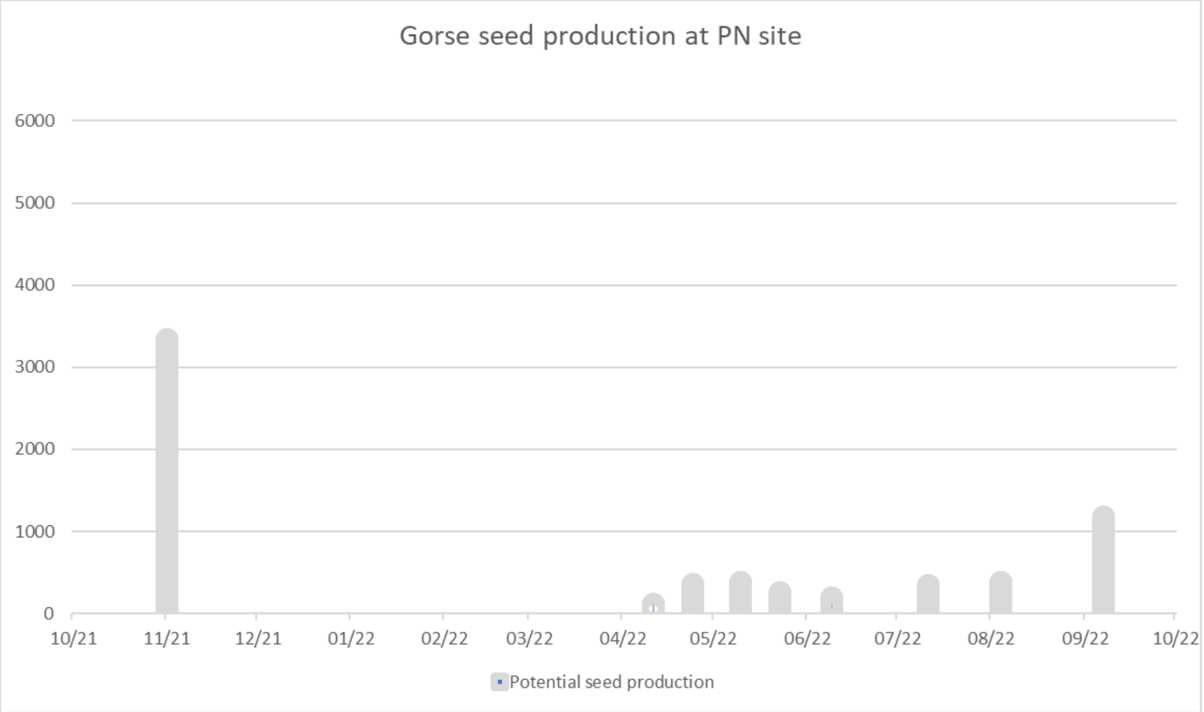
Results

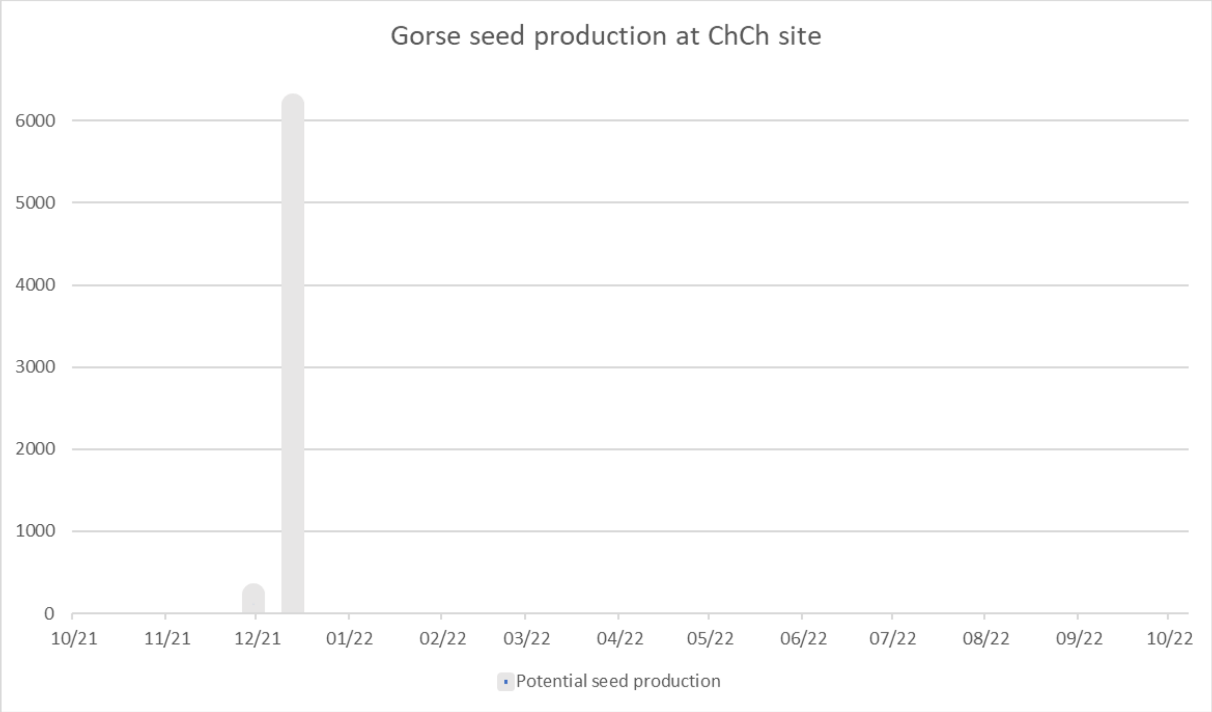
Pods marked and collected from tagged shoots to measure predation





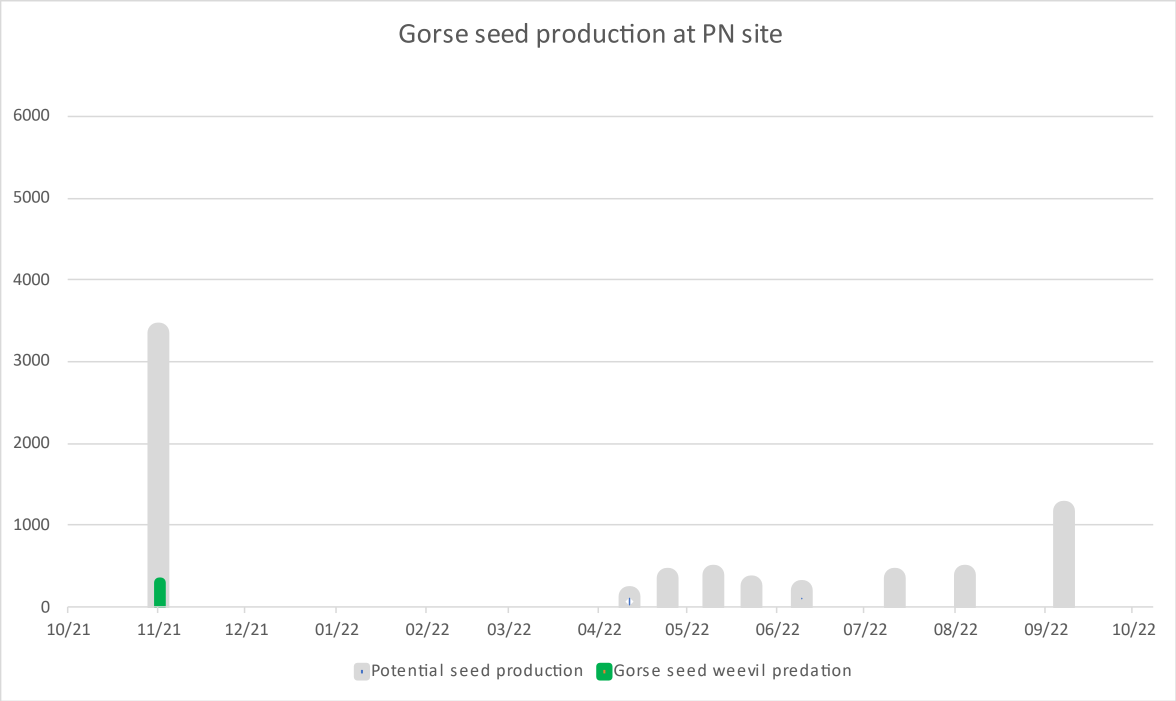
Potential seed production from pods collected

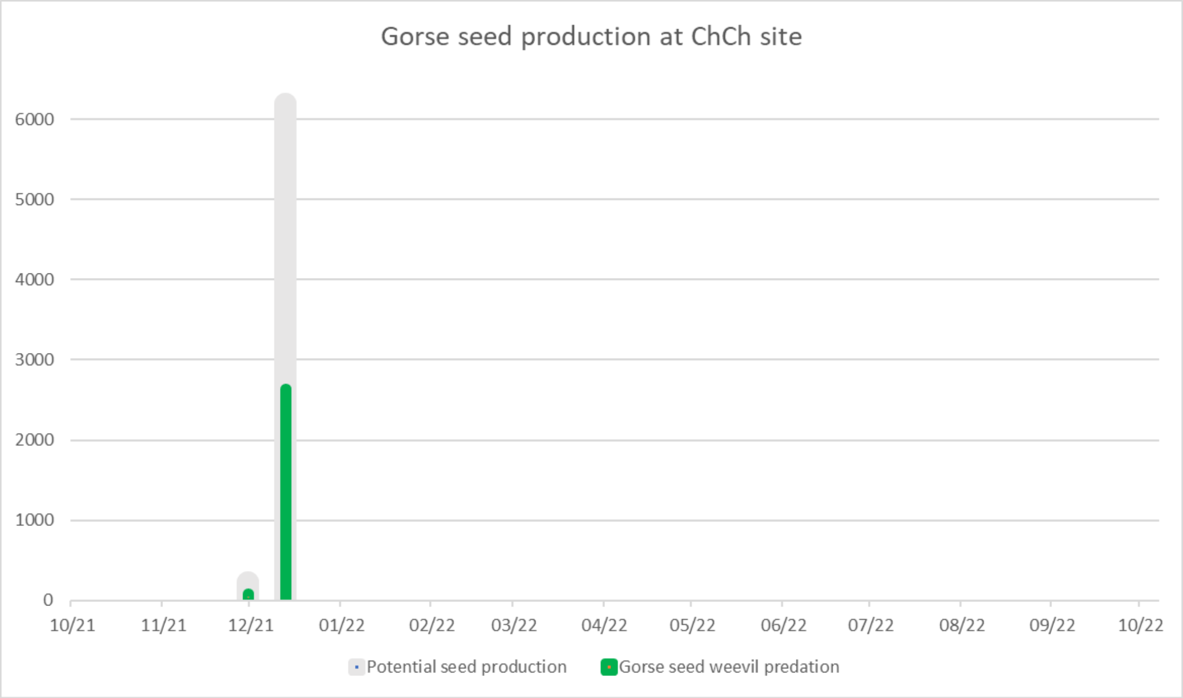




6585 seeds vs 6430 seeds

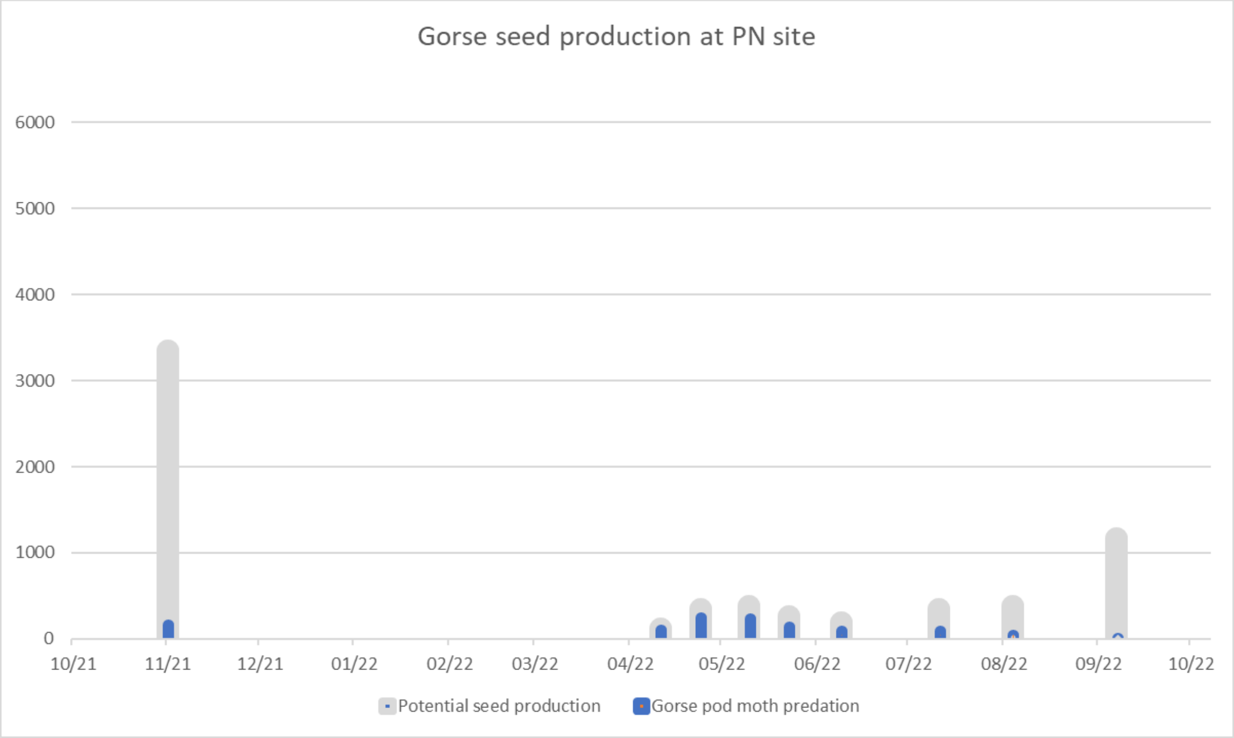
Seed predation by Gorse Seed Weevil

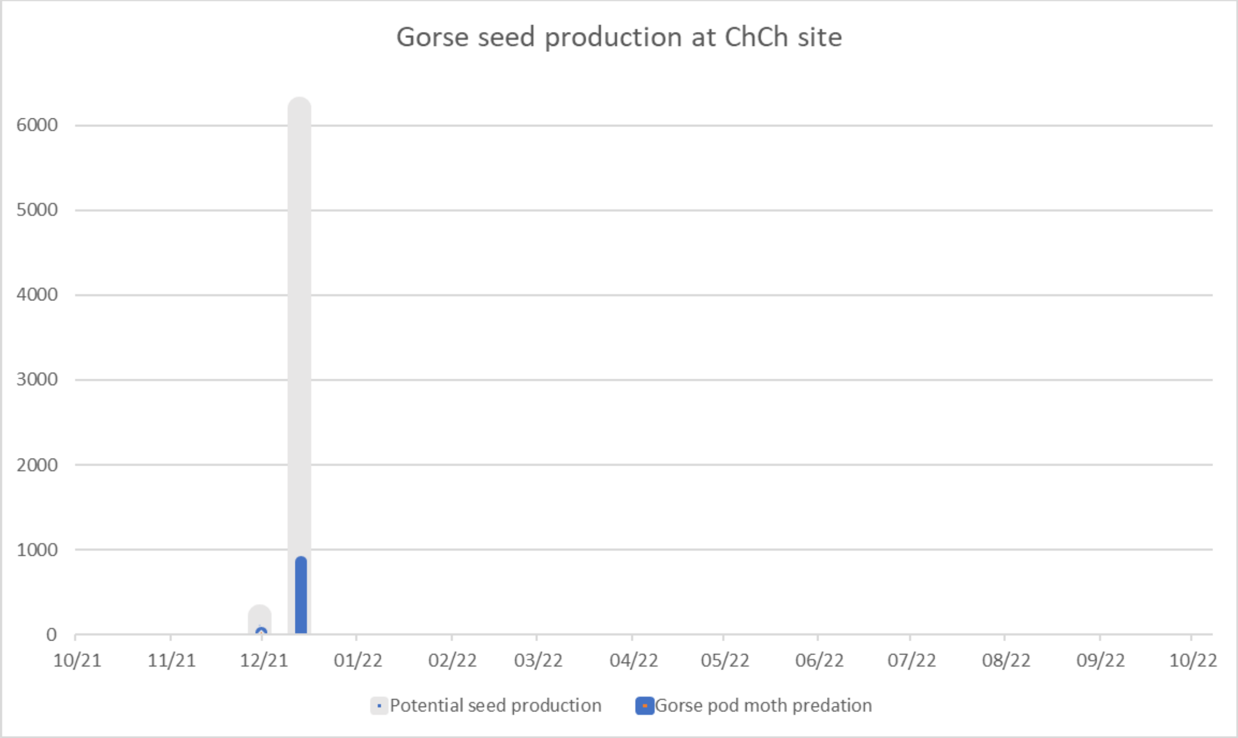




299 seeds vs 2724 seeds

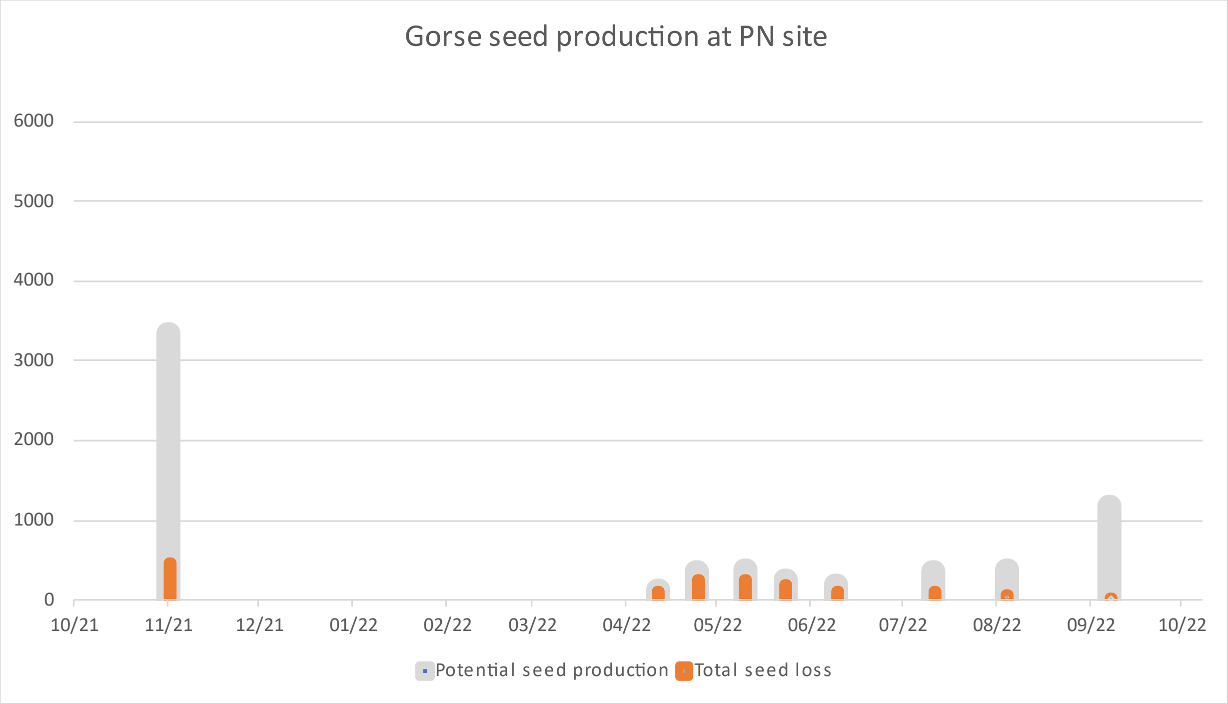
Seed predation by Gorse Pod Moth

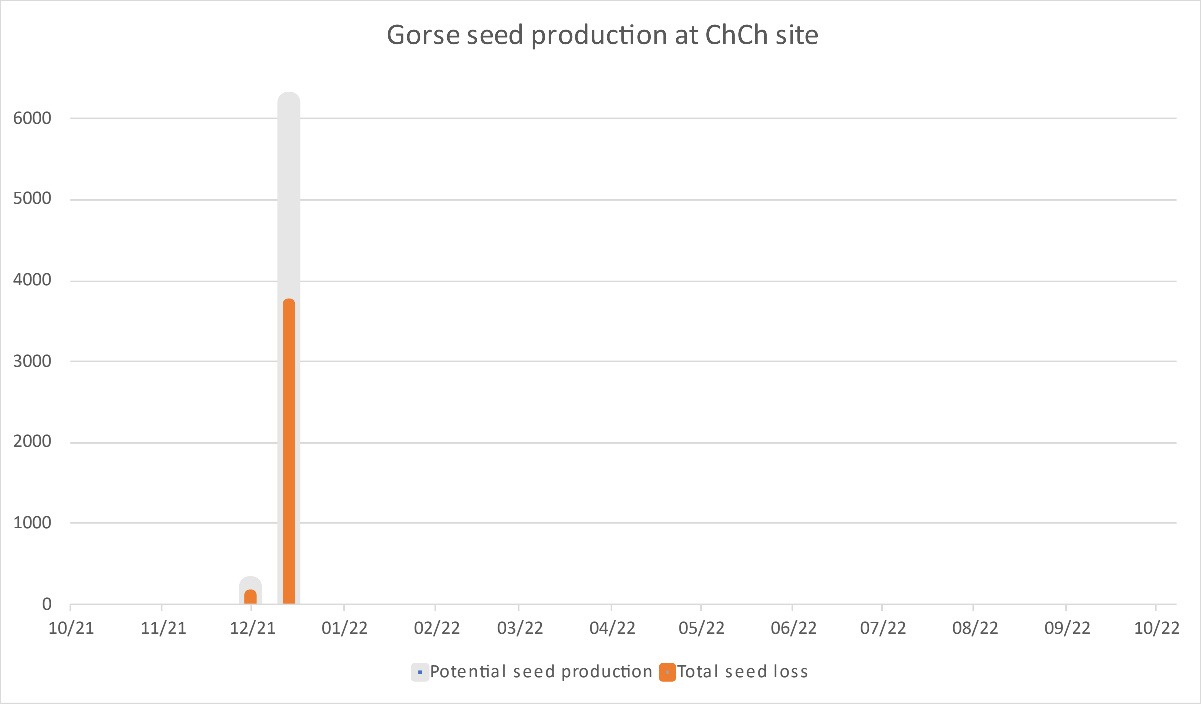




1127 seeds vs 894 seeds

Total seed predation/loss*

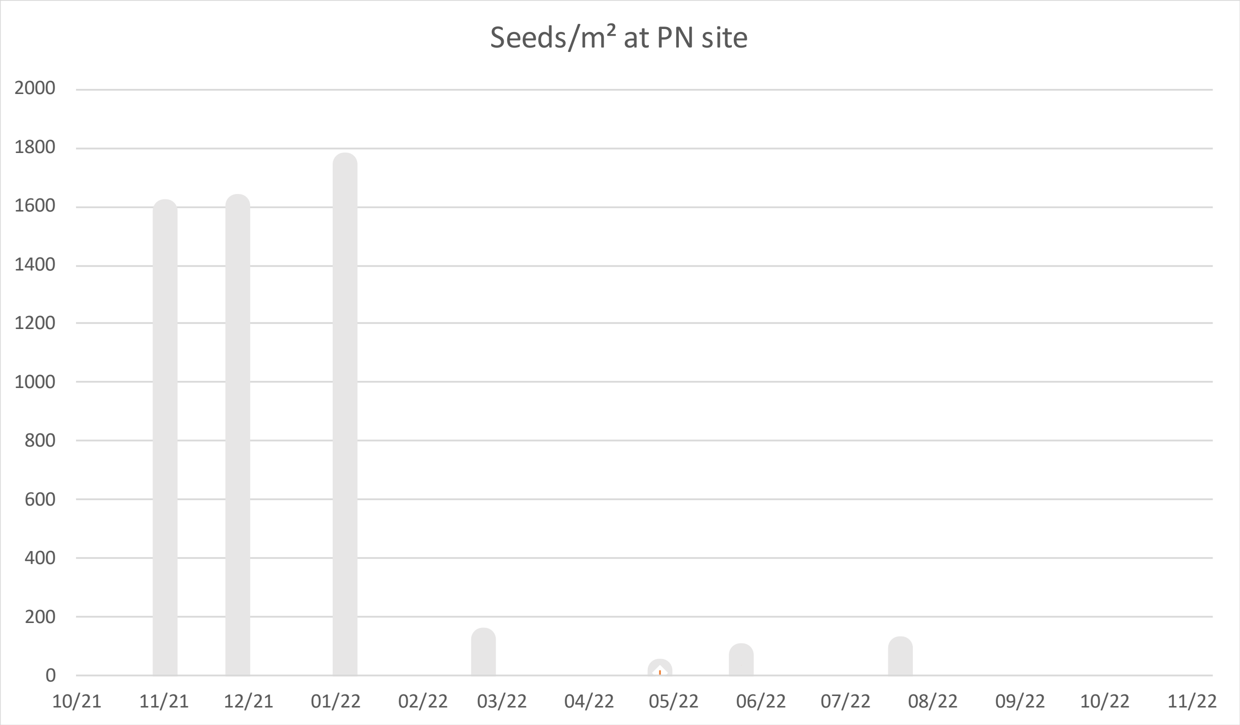


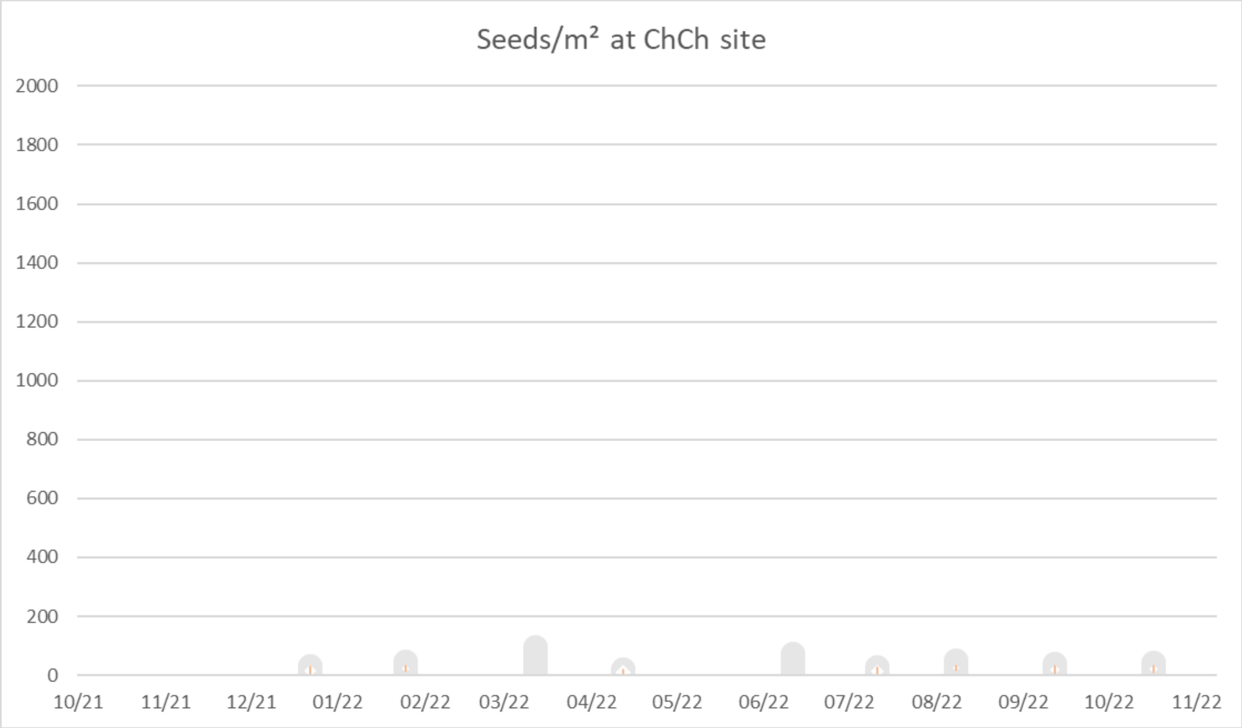


1563 seeds vs 3832 seeds

*Includes a small amount of seed loss due to late abortion and fungal infection

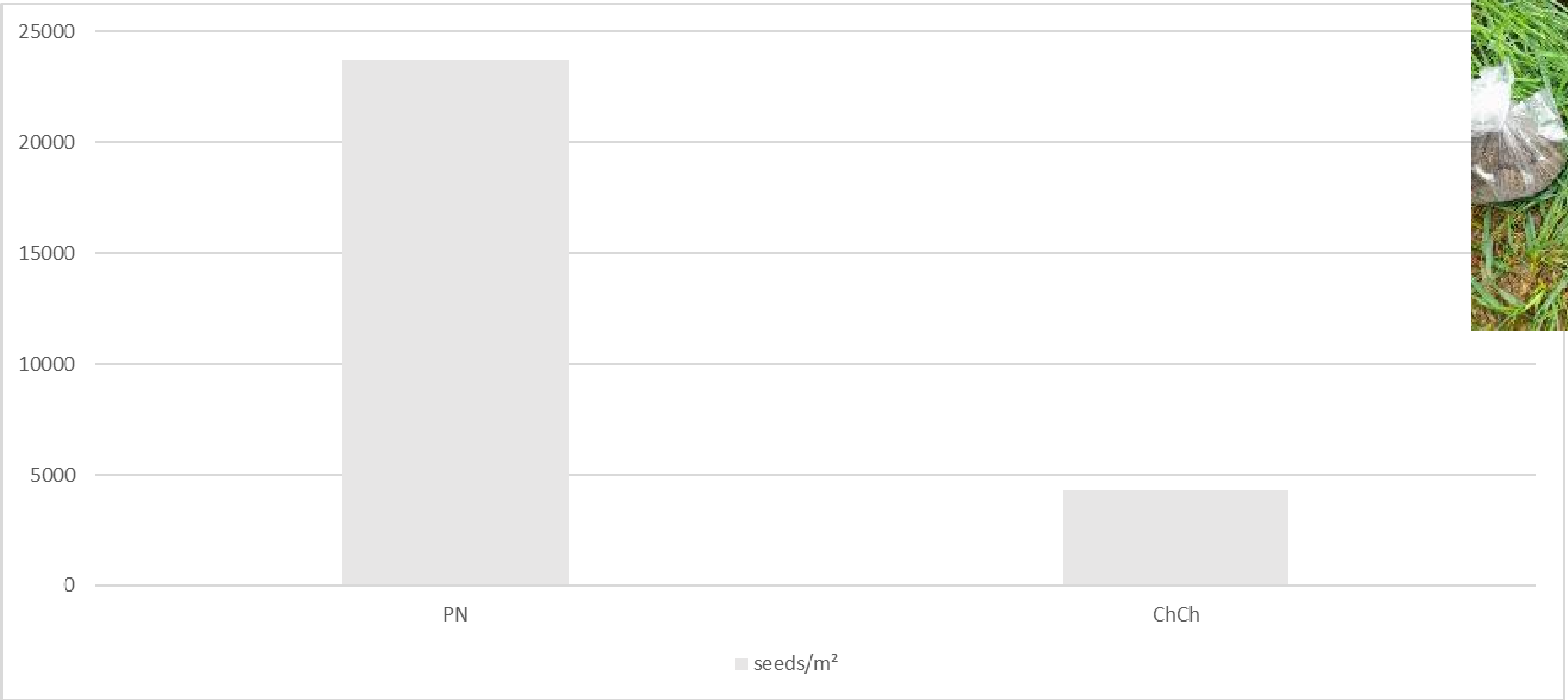
Seeds collected from seed trays (m^2)





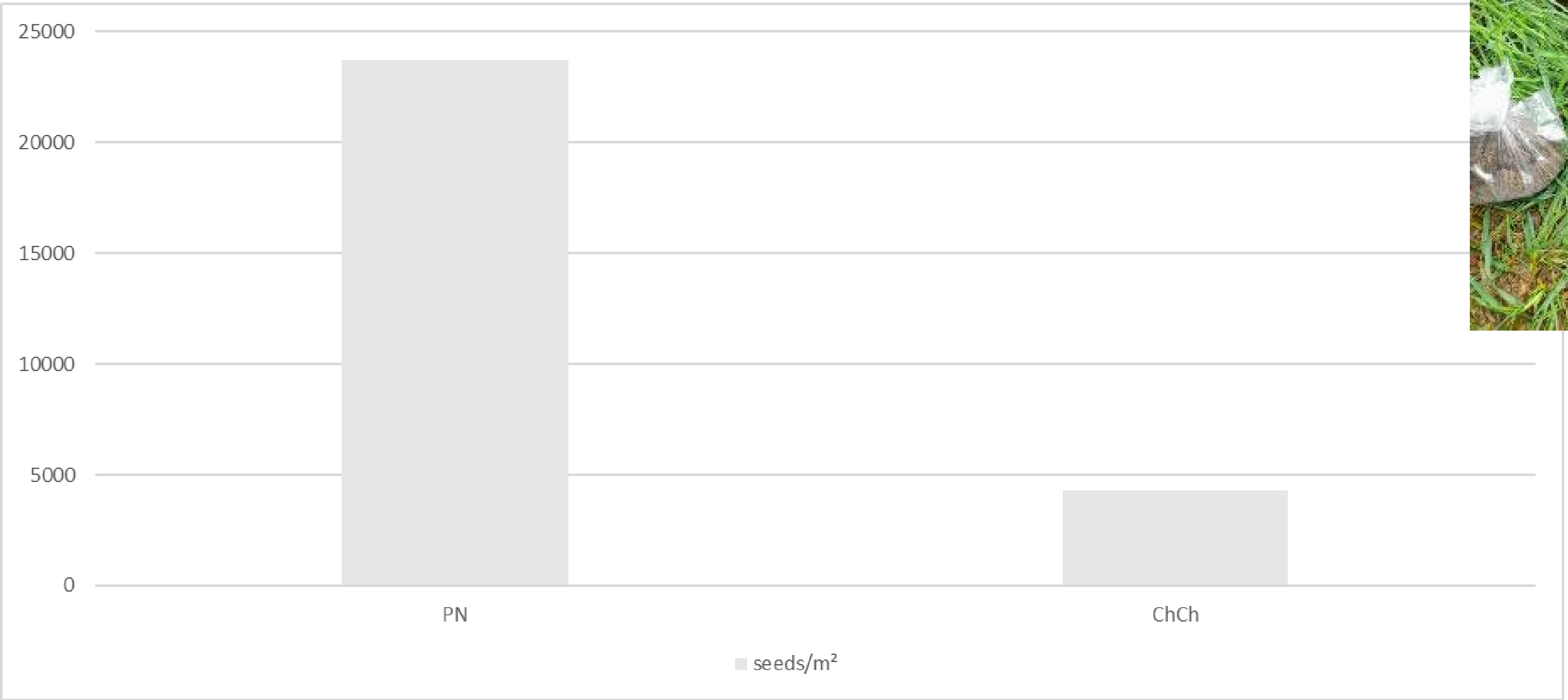
5,250 vs 429

Seeds collected from soil cores



23,695 vs 4,312

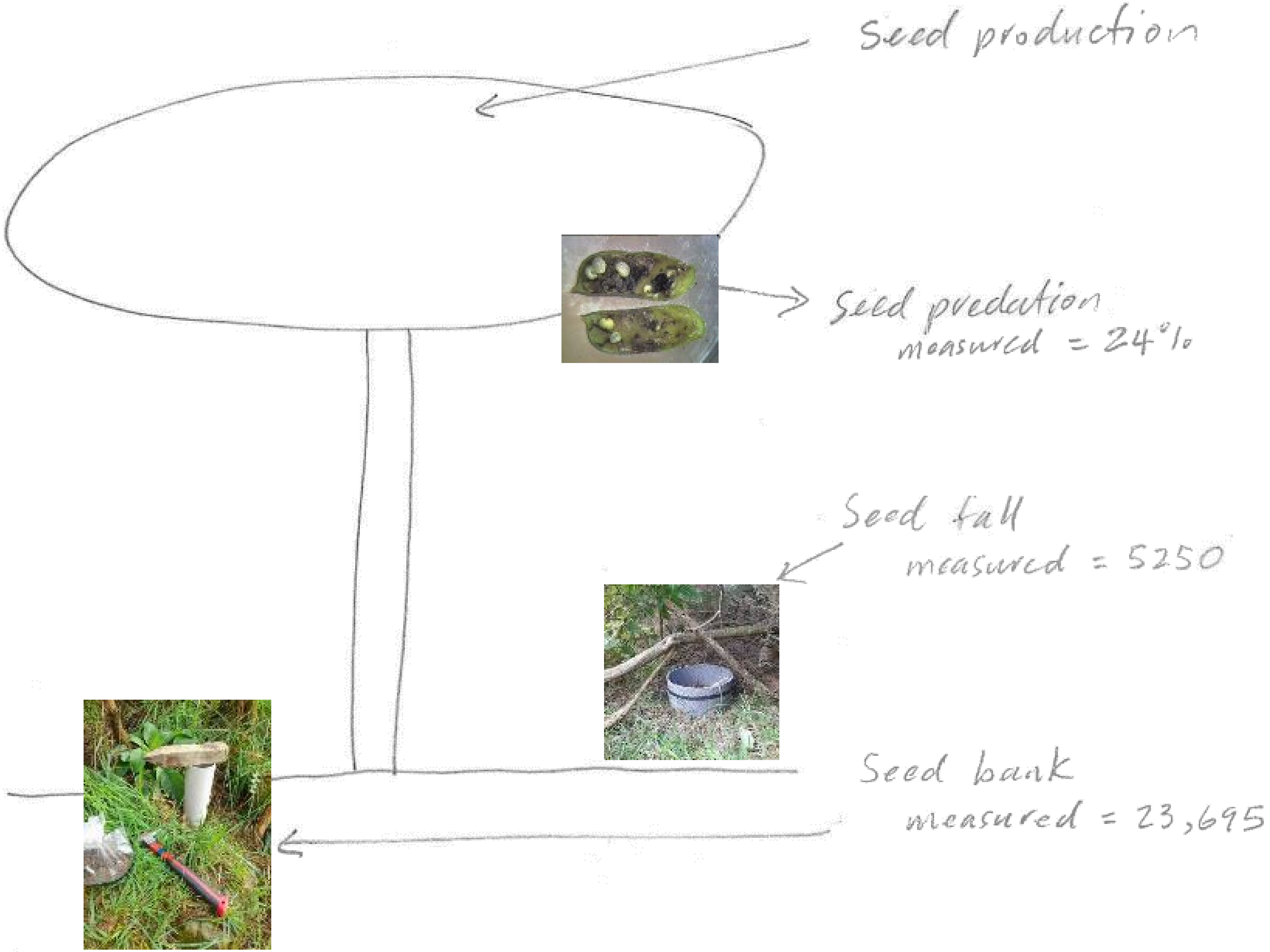
Seeds collected from soil cores



23,695 vs 4,312

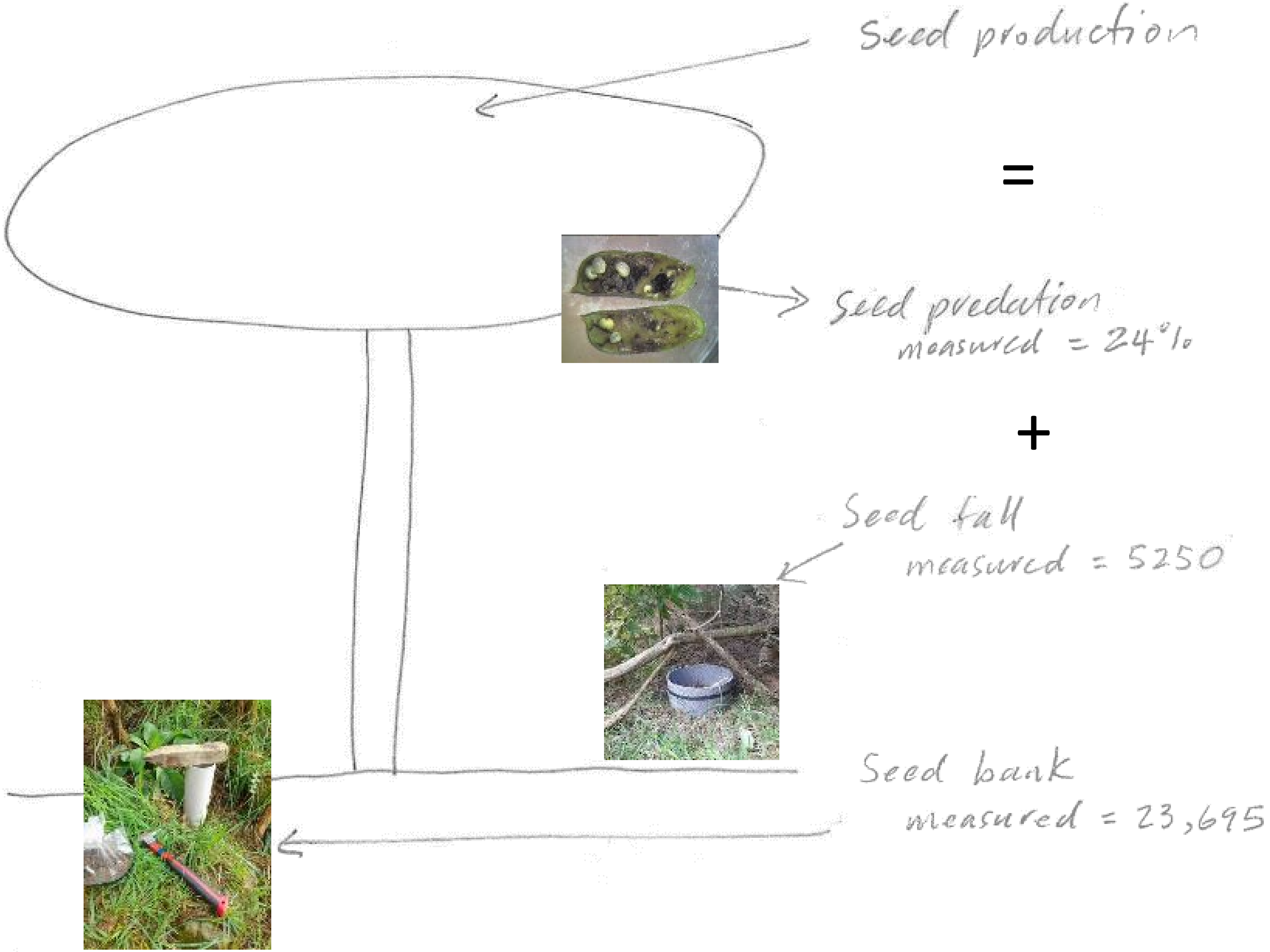
NB. Ivens (1978) found average of 10,000 seeds/m² at a location near our PN site.

PN - seeds/m²



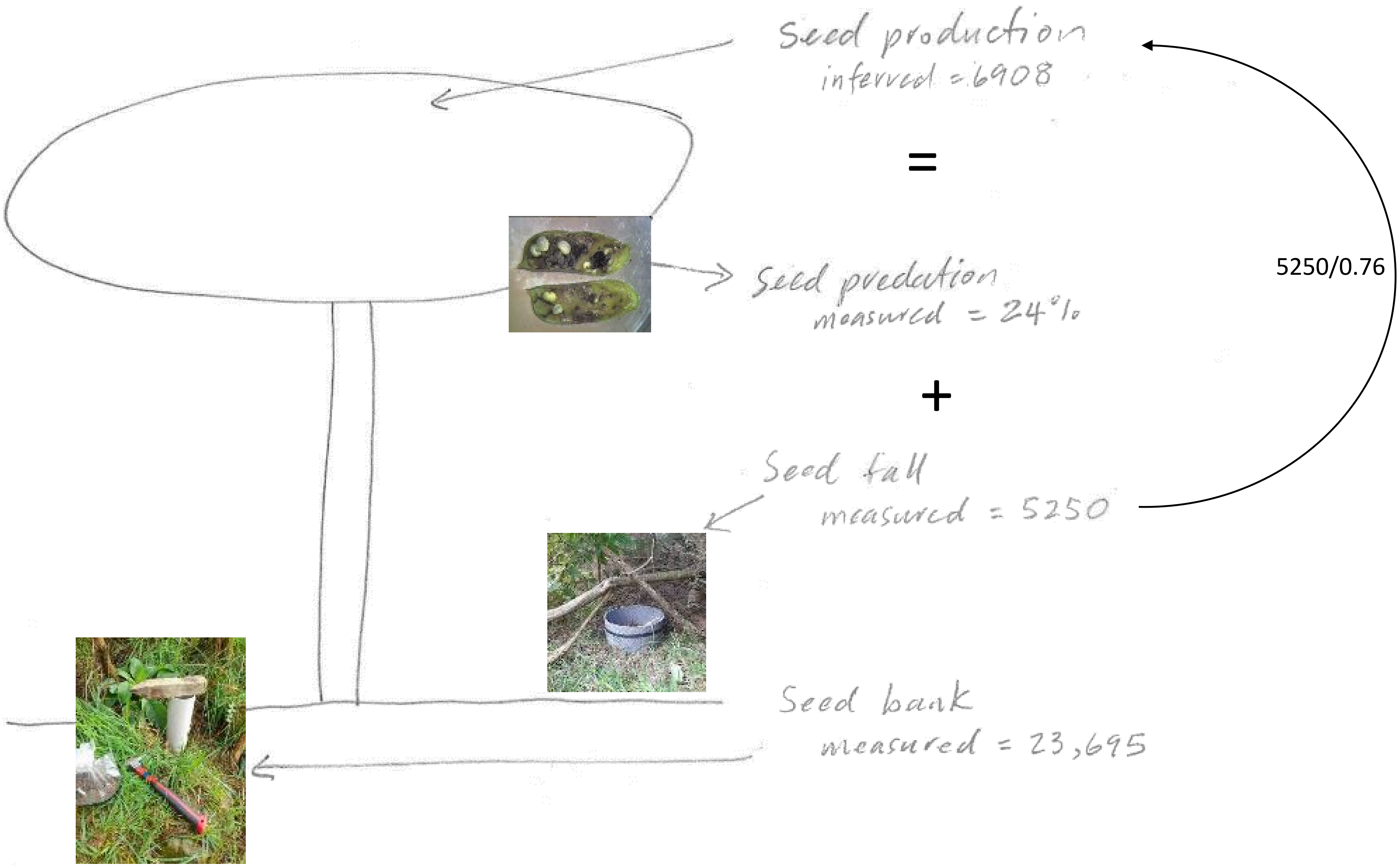
Seed production
Seed predation
measured = 24%
Seed fall
measured = 5250
Seed bank
measured = 23,695

PN - seeds / m^2



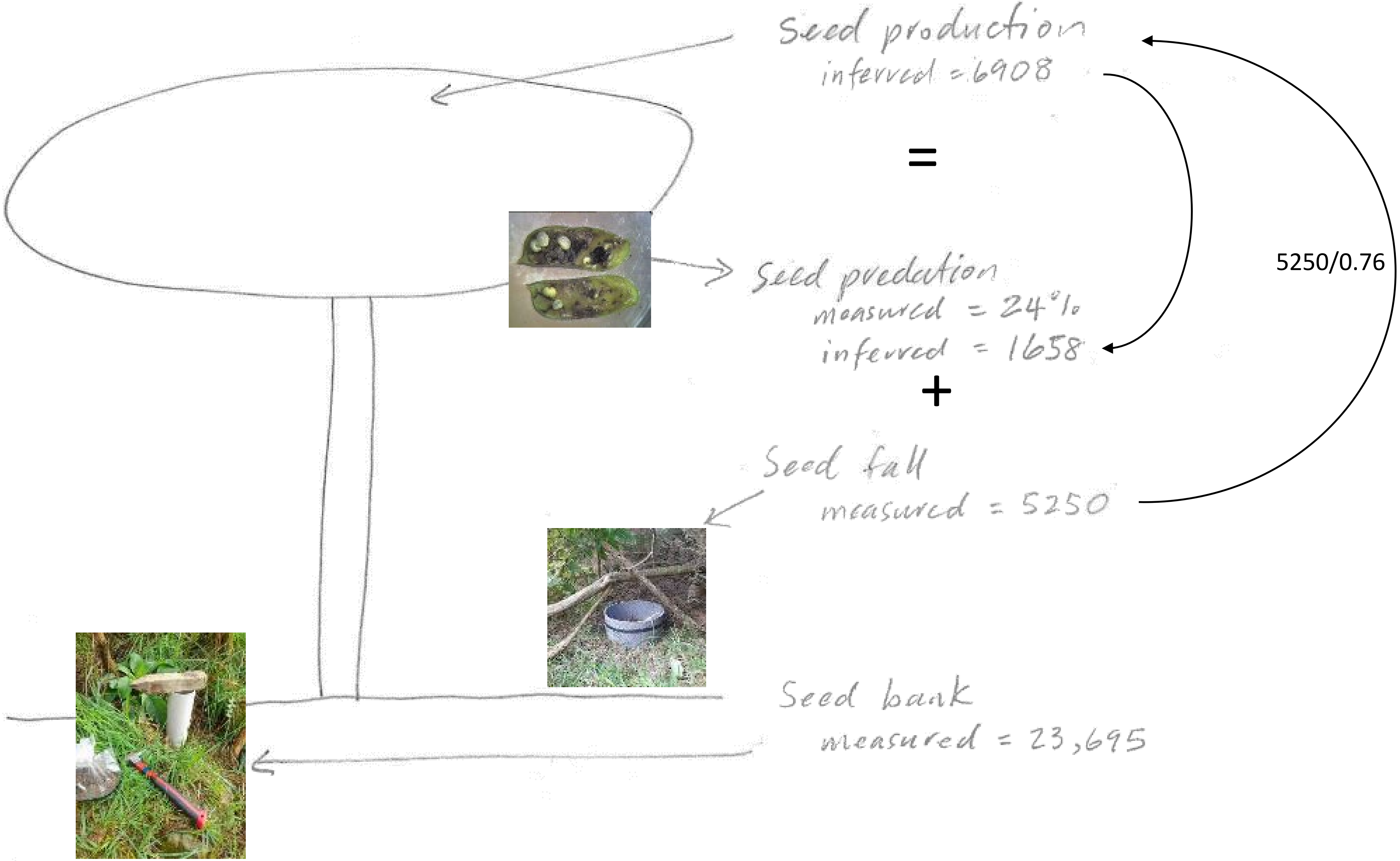
Seed production
=
Seed predation
measured = 24%
+
Seed fall
measured = 5250
Seed bank
measured = 23,695

PN - seeds/m²

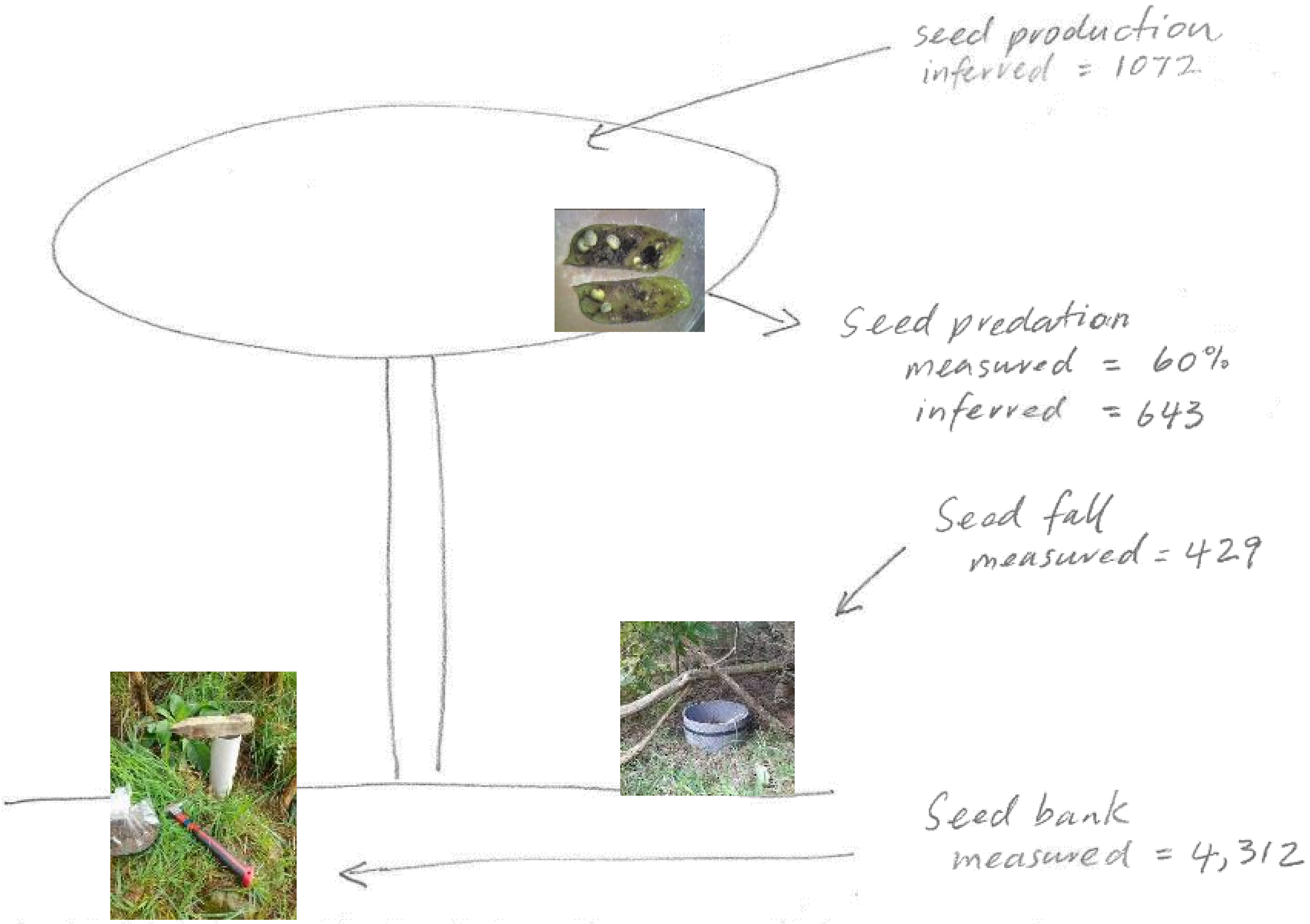


Seed production
inferred = 6908
=
Seed predation
measured = 24%
+
Seed fall
measured = 5250
5250/0.76
Seed bank
measured = 23,695

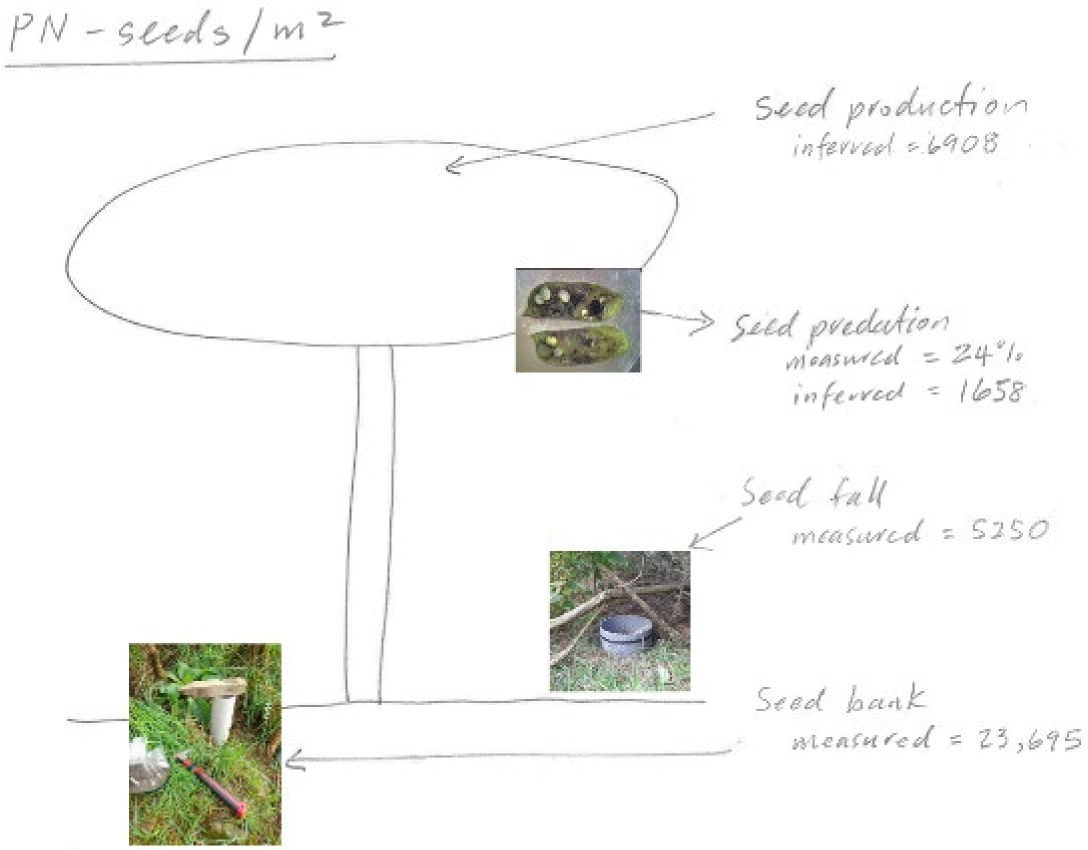
PN - seeds/m²

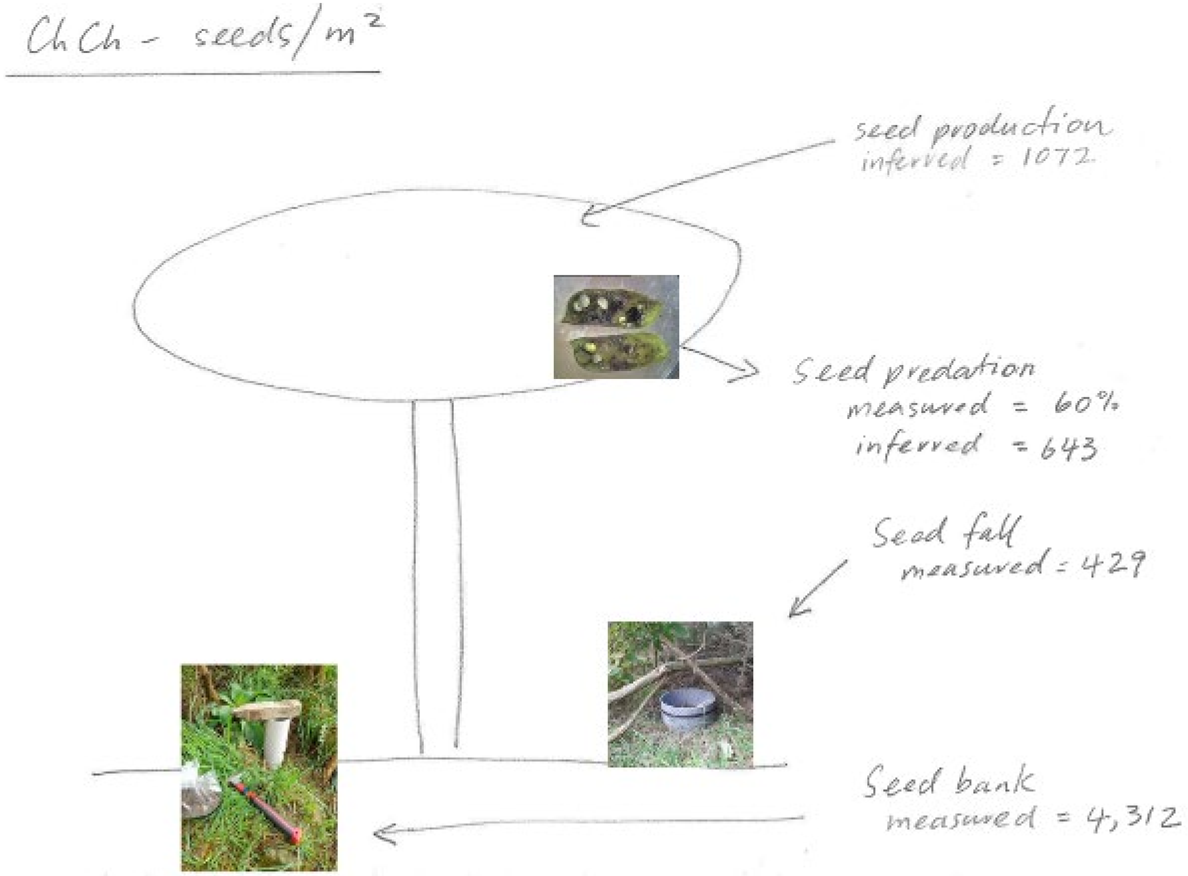

Seed production
inferred = 6908
=
Seed predation
measured = 24%
inferred = 1658
+
Seed fall
measured = 5250
5250/0.76
Seed bank
measured = 23,695

ChCh - seeds/m²

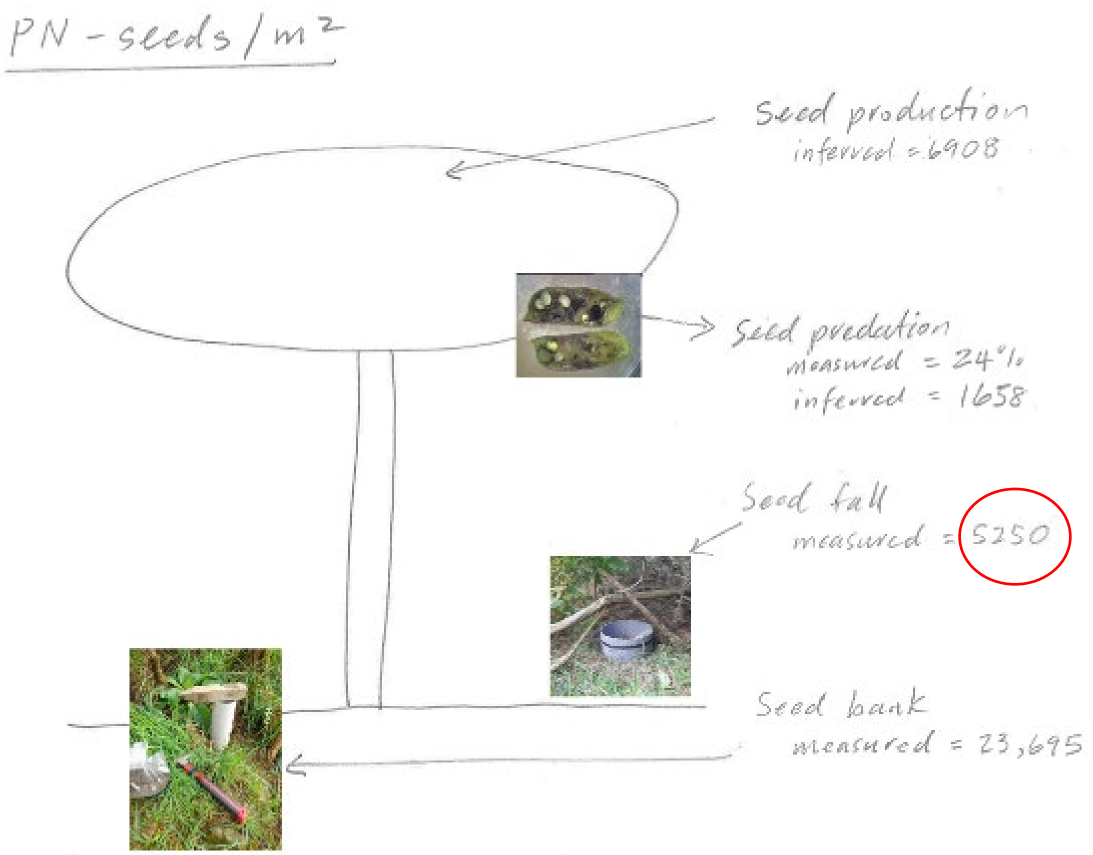


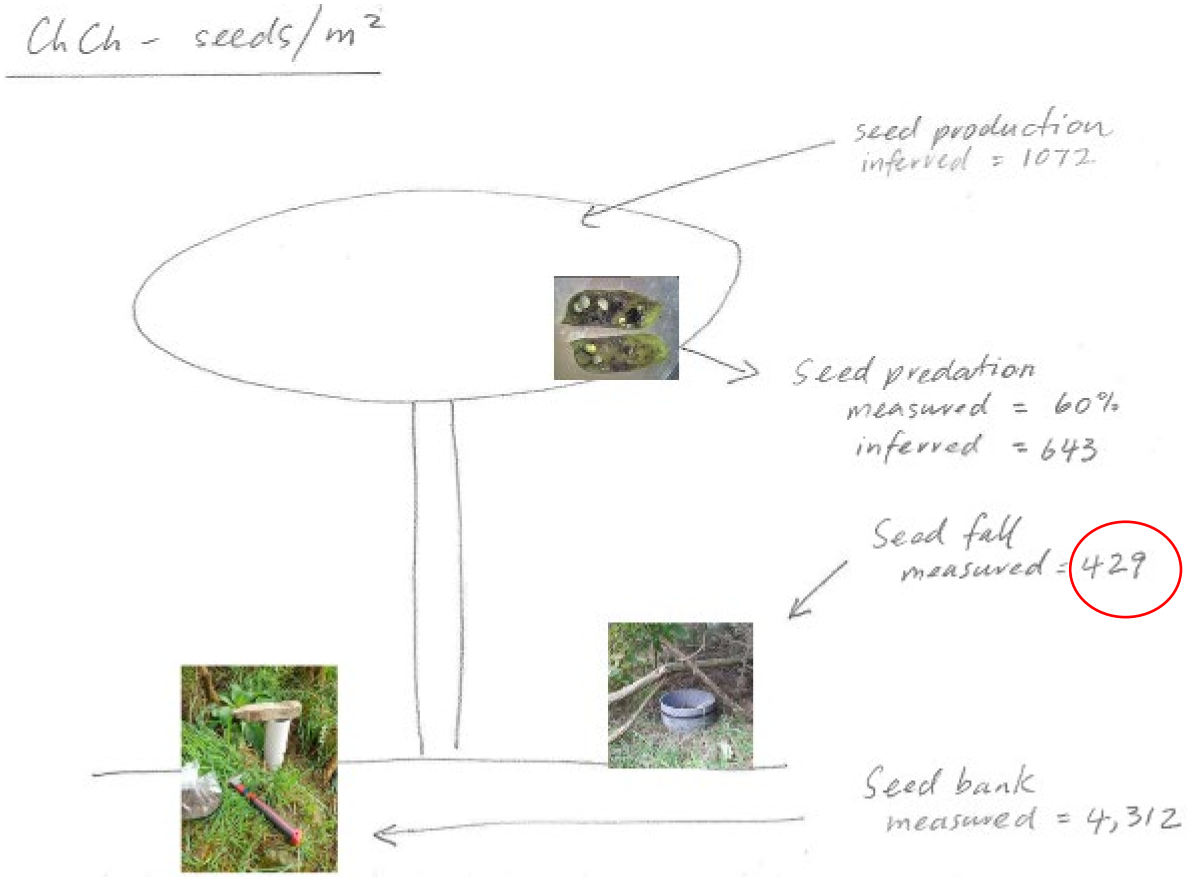
Reduced seed production figures – both sites





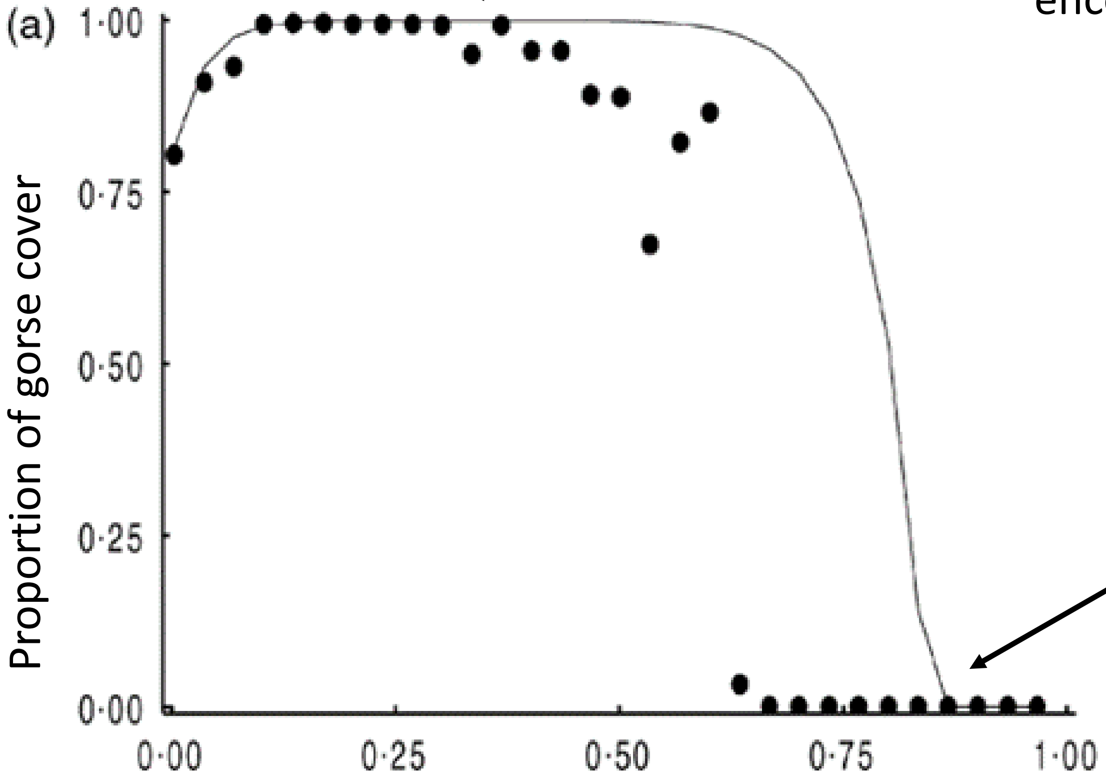
Reduced seed production figures – both sites





Gorse cover is driven by disturbance and recruitment...

Moderate disturbance encourages recruitment



Proportion of gorse cover

Probability of disturbance/year

Very frequent disturbance leads to extinction, no recruitment.

NB. Proportion of gorse cover when model assumes seedling survival is low

… and seed production.

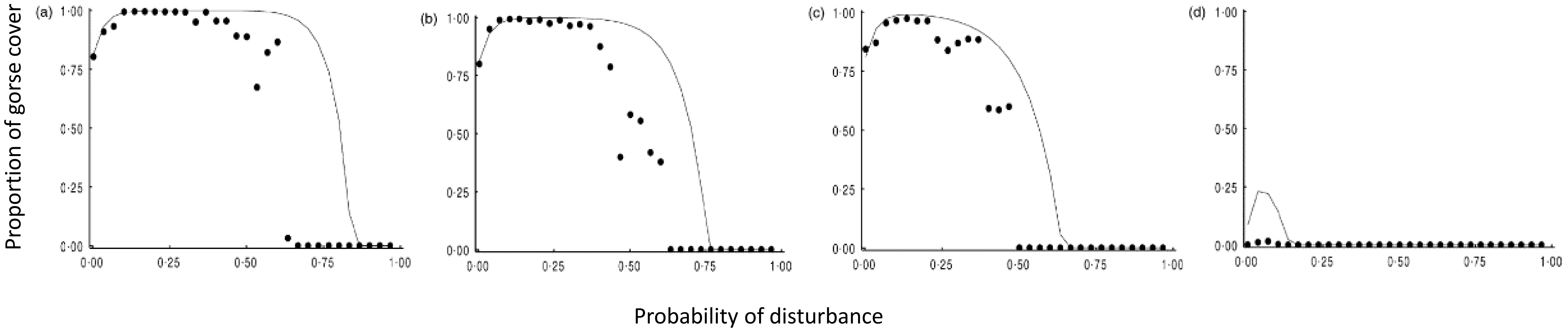
50%, 75% and 95% seed reduction scenarios

Natural seed production*
(8,888 seeds/m²)

(4,444 m²)

(2,222 m²)

(444 m²)



* Based on seed production estimates by R.L. Hill (unpublished data)

PN data

50%, 75% and 95% seed reduction scenarios

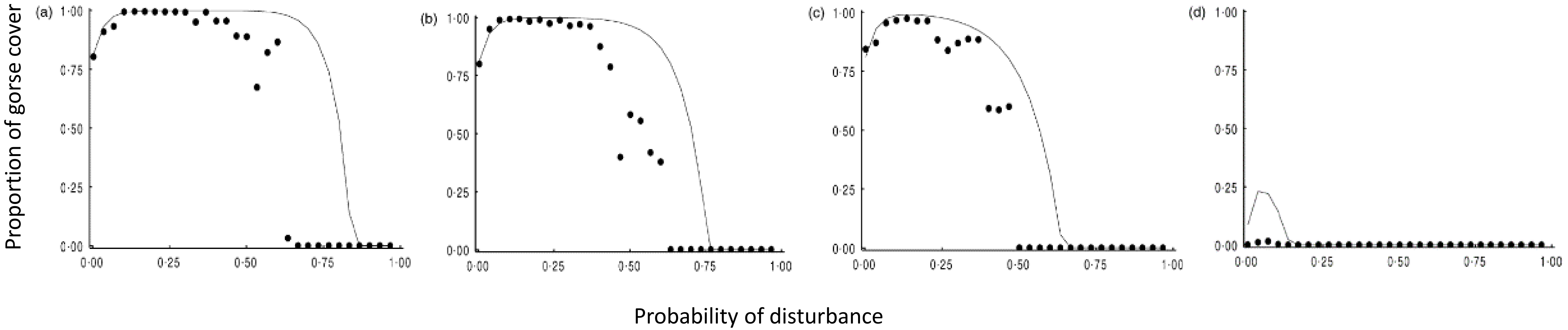
Natural seed production
(8,888 seeds/m²)

(4,444 m²)

(2,222 m²)

(444 m²)

5250



Seed predation is insufficient to contribute to a reduction in our PN gorse population unless disturbance is very frequent (at least once every 2 years) and seedling survival is low.

ChCh data

50%, 75% and 95% seed reduction scenarios

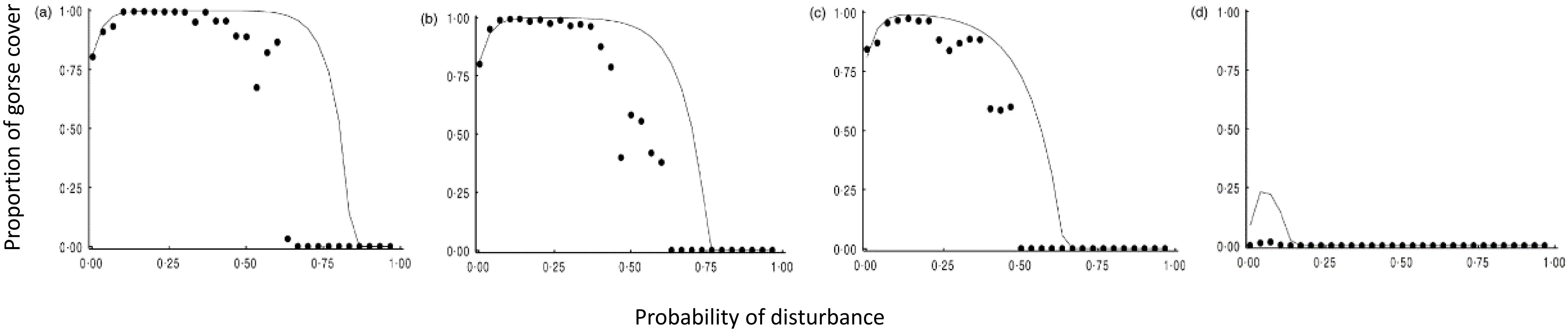
Natural seed production
(8,888 seeds/m²)

(4,444 m²)

(2,222 m²)

(444 m²)

429



Seed predation is sufficient to contribute to a reduction in our ChCh gorse population regardless of disturbance, assuming seedling survival is low.

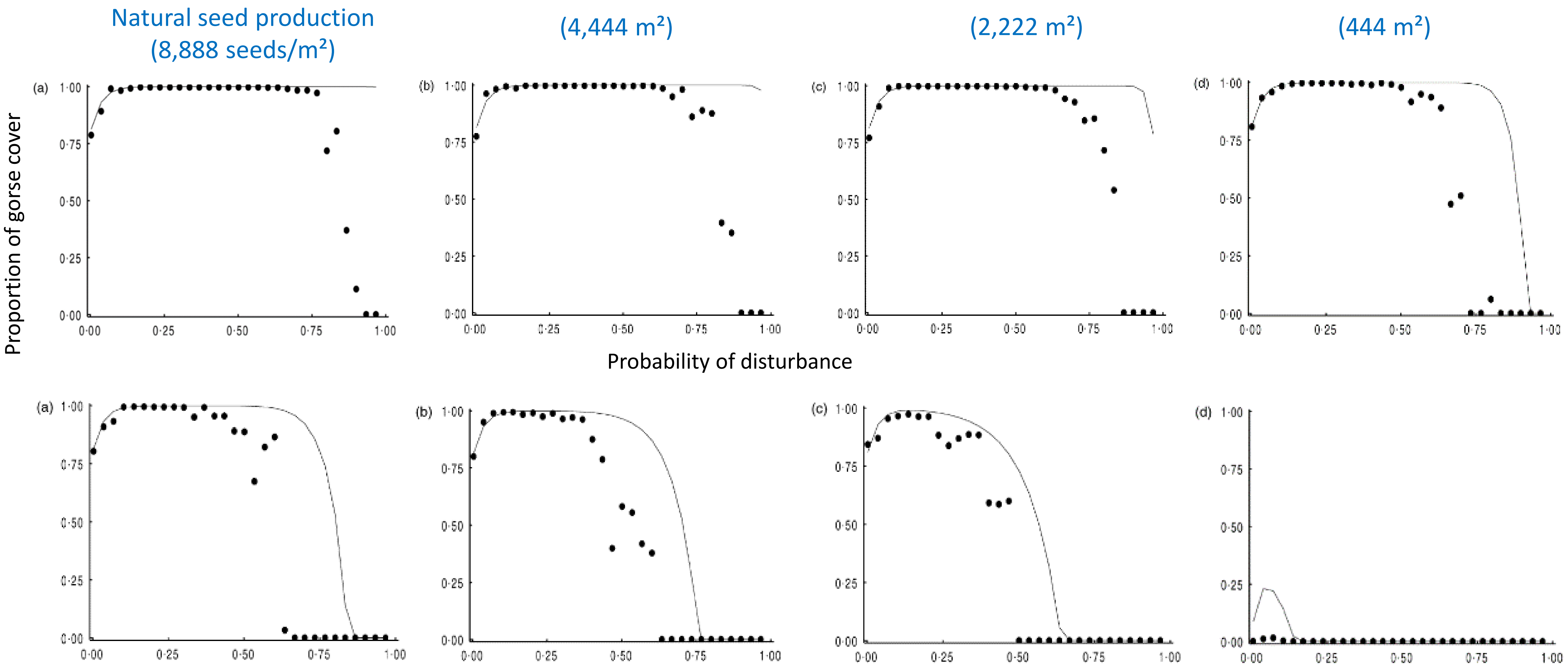
So why do we still have gorse at the ChCh site?

ChCh site had a reasonably even cohort established after fire, i.e. large disturbance with high seedling survival.

Site now needs no further disturbance to prevent recruitment, or if disturbance occurs management practices to reduce seedling survival.

Disturbance and seedling recruitment parameters are critical.

Gorse abundance when seedling survival is high vs low



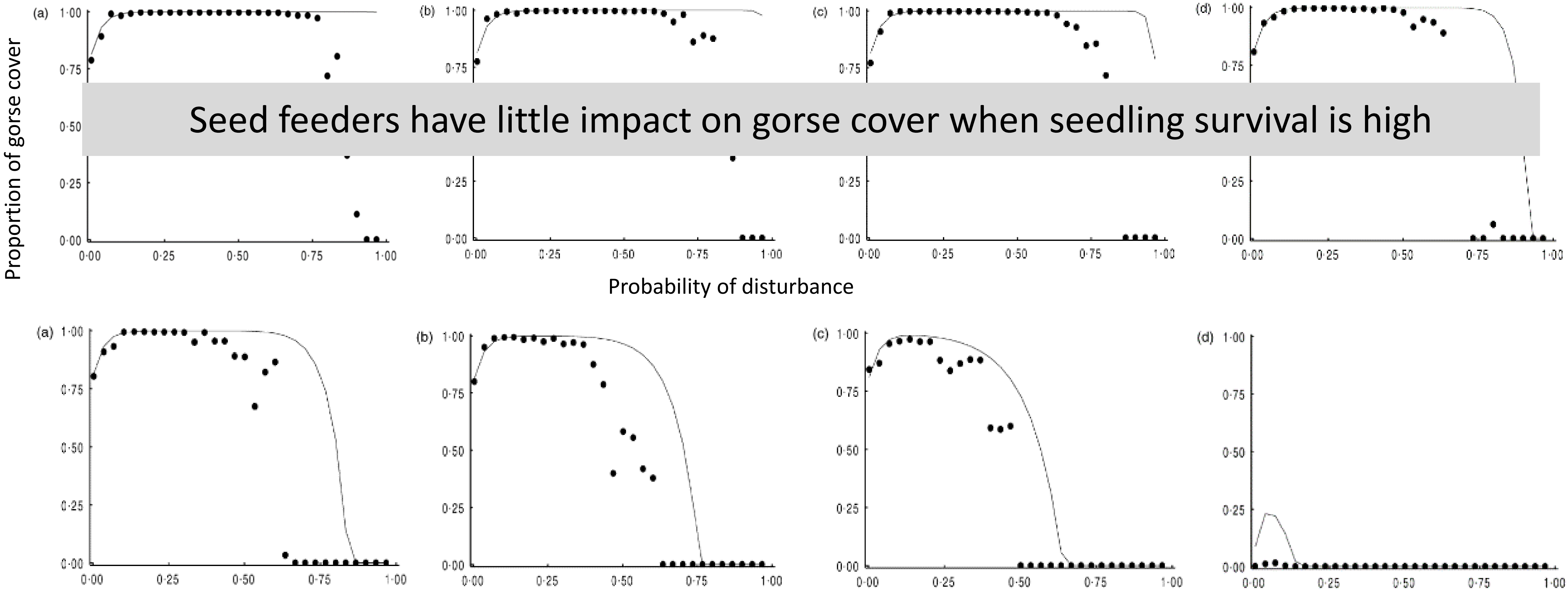
Gorse abundance when seedling survival is high vs low

Natural seed production (8,888 seeds/m²)

(4,444 m²)

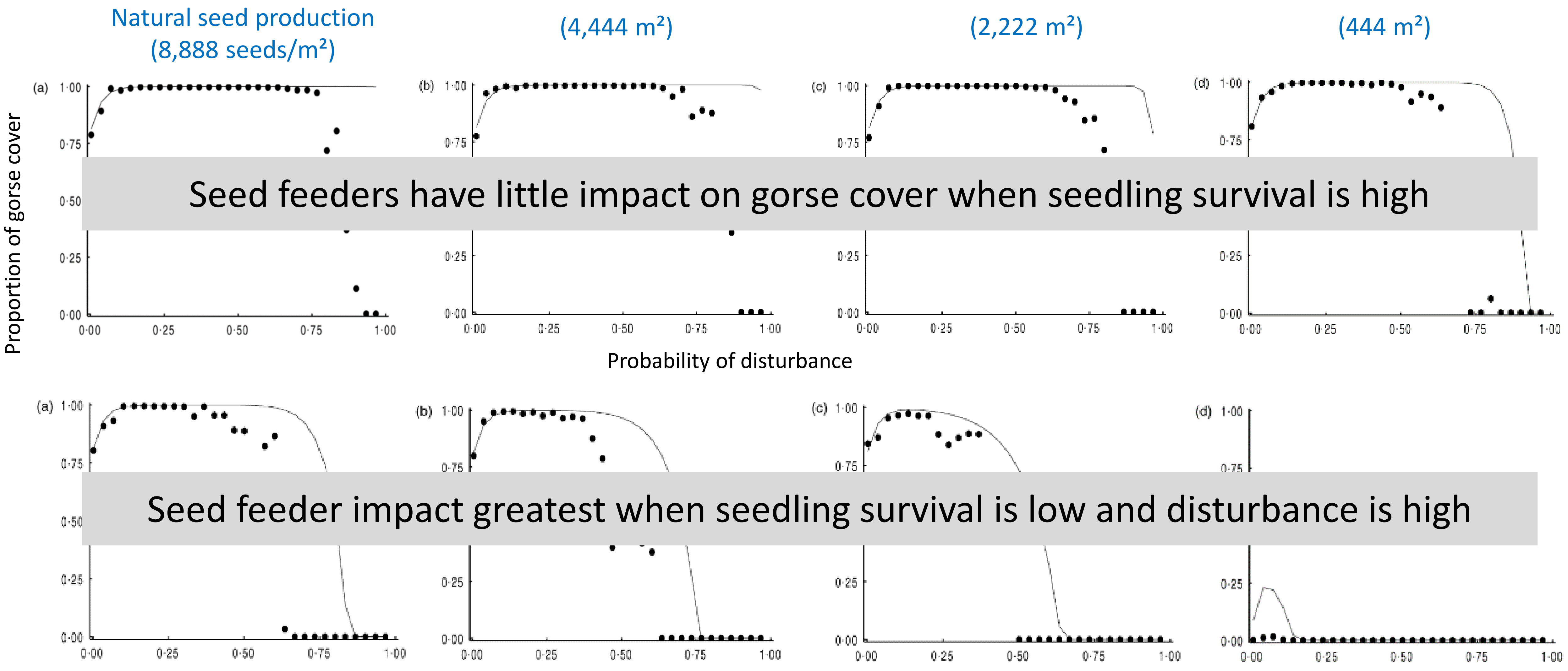
(2,222 m²)

(444 m²)



Seed feeders have little impact on gorse cover when seedling survival is high

Gorse abundance when seedling survival is high vs low



Summary

Sites varied hugely. Summer seeding at ChCh vs. summer, autumn & winter at PN.

Seed predation likely to be sufficient at ChCh to help reduce gorse cover but significant seed production escaped predation at PN and gorse cover will likely persist without good land management decisions.

Managing for low seedling recruitment is key, and in order to obtain the greatest impact from seed feeding biocontrol agents management practices that kill plants, prevent or substantially reduce subsequent recruitment and reduce seedling survival will be required.

Recent evidence from broom studies suggests pollinator management could also be critical to gorse seed production and reducing seed banks (Paynter et al. 2010).

Take home message

Biocontrol can assist to reduce long-term gorse cover under certain circumstances by driving seed fall below threshold levels. However, good land management decisions will still be required if there is a disturbance to target seedlings before they flower.

Acknowledgements

- We would like to thank Ralph Pugmire at Palmerston North and the Christchurch city council for access to study sites
- This work was funding by MPI
- Thanks to Quentin Paynter for useful comments