Integrating weed seed-loss pathways for resilient weed management

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Why is weed management a persistent challenge?

- Most weed management strategies target emerged plants, leaving the soil seedbank as a major source of future weed infestations.
- Weed population persistence is governed by the balance between seed inputs (seed rain) and seed losses from the soil seedbank
- Sustainable integrated weed management (IWM) requires strategies that target multiple stages of the weed life cycle, reducing seed return while enhancing seedbank depletion.

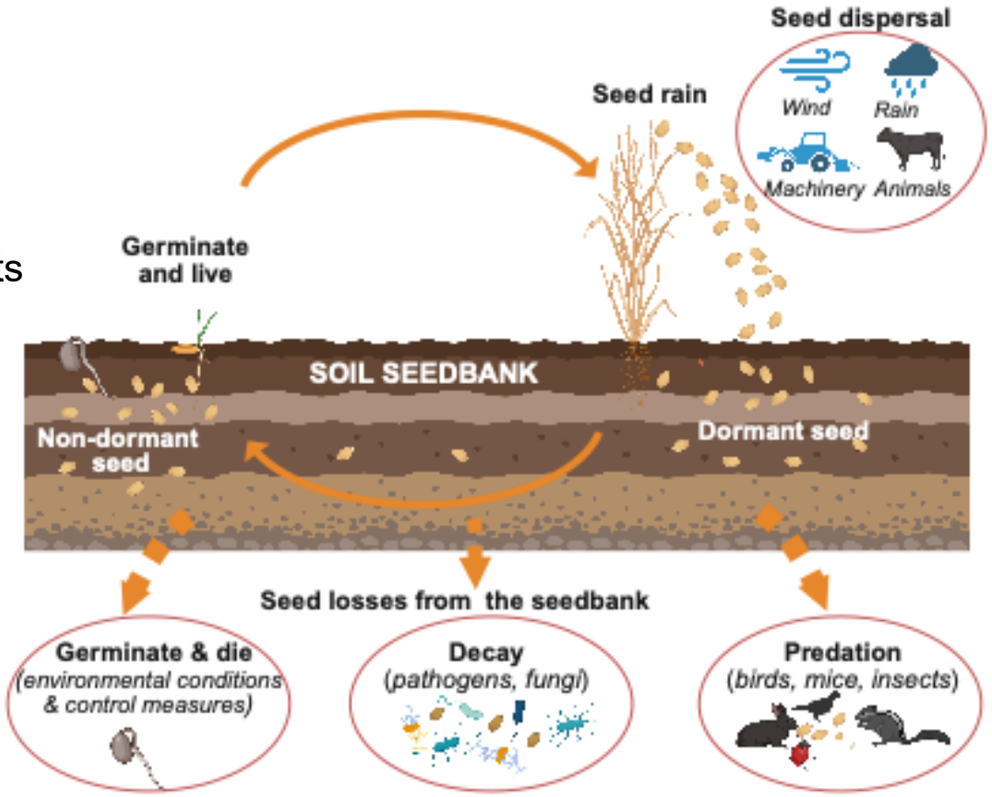


Fig. 1: Fate of weed seeds (*adapted from Menalled et al., 2008*).

(Buhler et al. 1997)

1. Can top-cutting (pre-harvest removal of seed heads before shedding) reduce weed seed return across species, crop varieties, and seasons?



Materials and methods

1. **Four species**: *Alopecurus myosuroides, Lolium multiflorum, Avena fatua, and Bromus secalinus*
2. **Two winter wheat varieties**: short- and tall-strawed
3. **Five cutting treatments**: based on weed anthesis phenology (early, mid, late flowering stages)
4. **Cutting procedure**: Seed heads above the canopy were manually cut with a hedge trimmer to simulate a top-cutting machine, then removed and stored.
    - Fixed cutting height (~3 cm above canopy via string guide)
5. **Measurements**: weed/crop height, number of seed heads (above/below canopy), number of cut vs remaining seed heads, and seed viability
6. **Seasons**: 2023/24 and 2024/25, across two sites

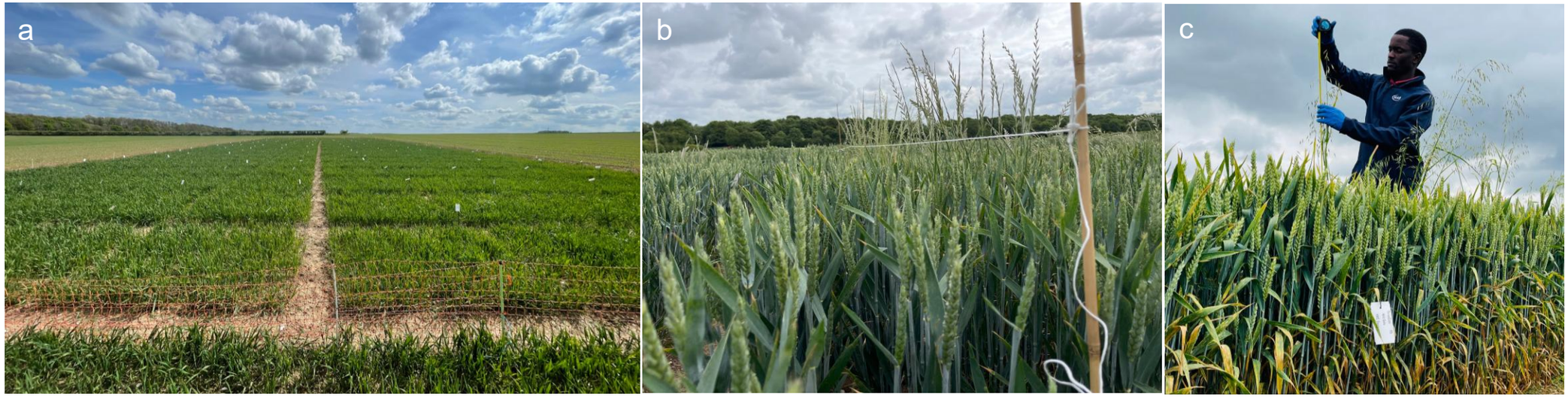


Fig. 2: Experimental overview.

Results

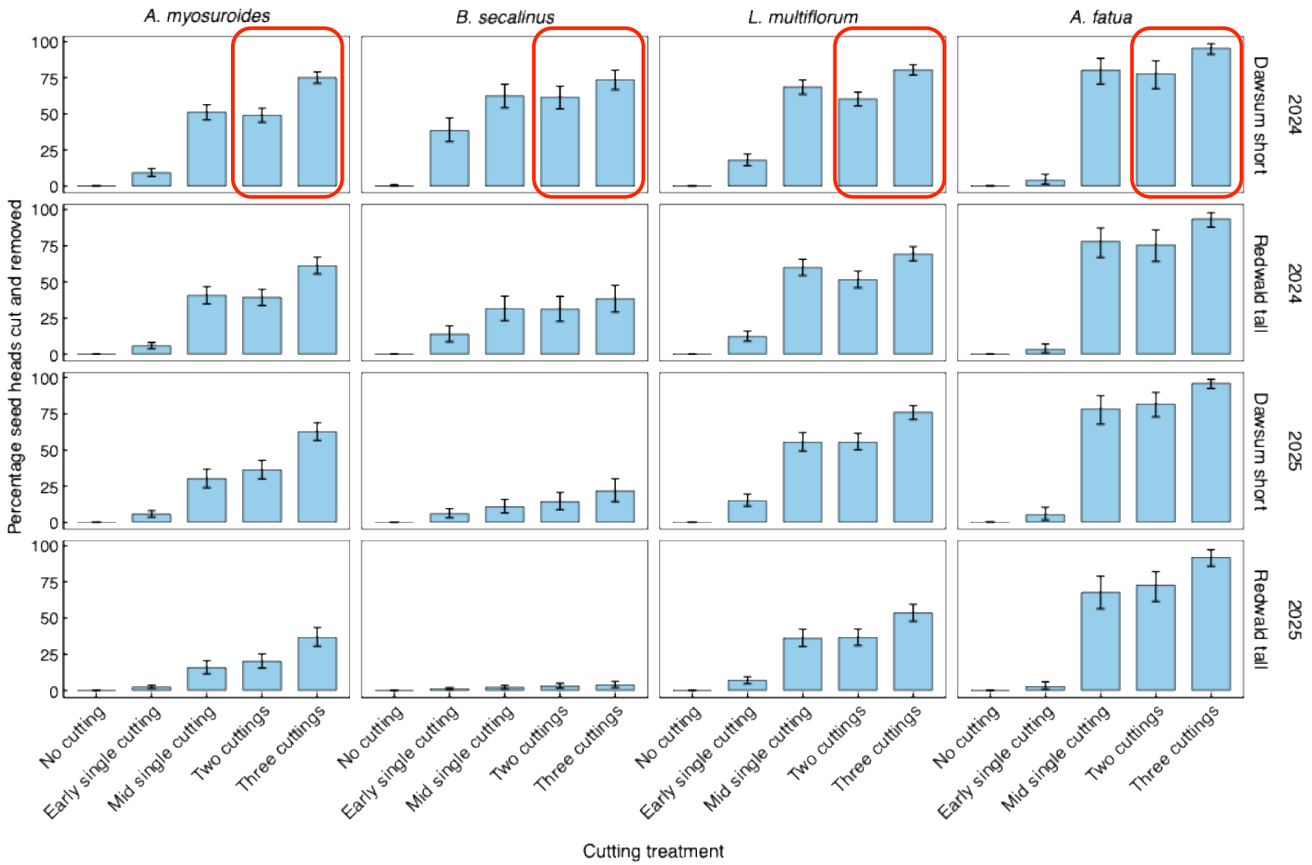


Fig. 3: Top-cutting efficacy across species, varieties, and years.

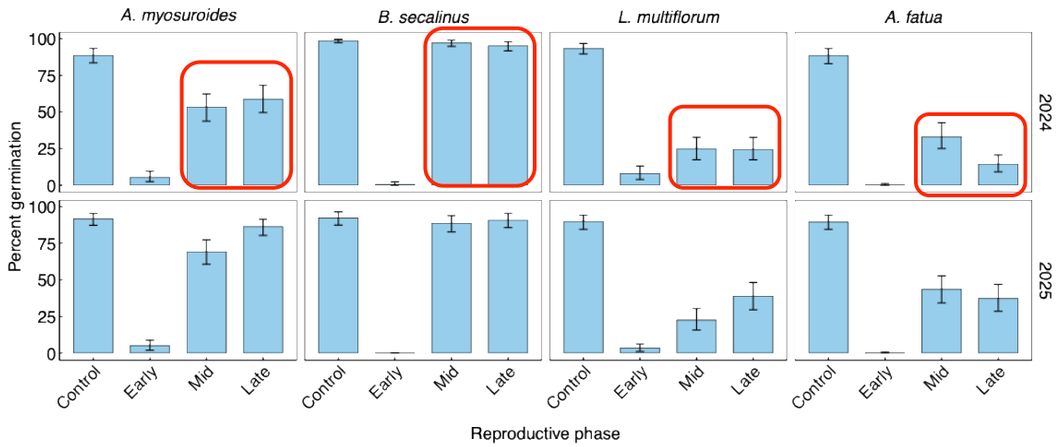


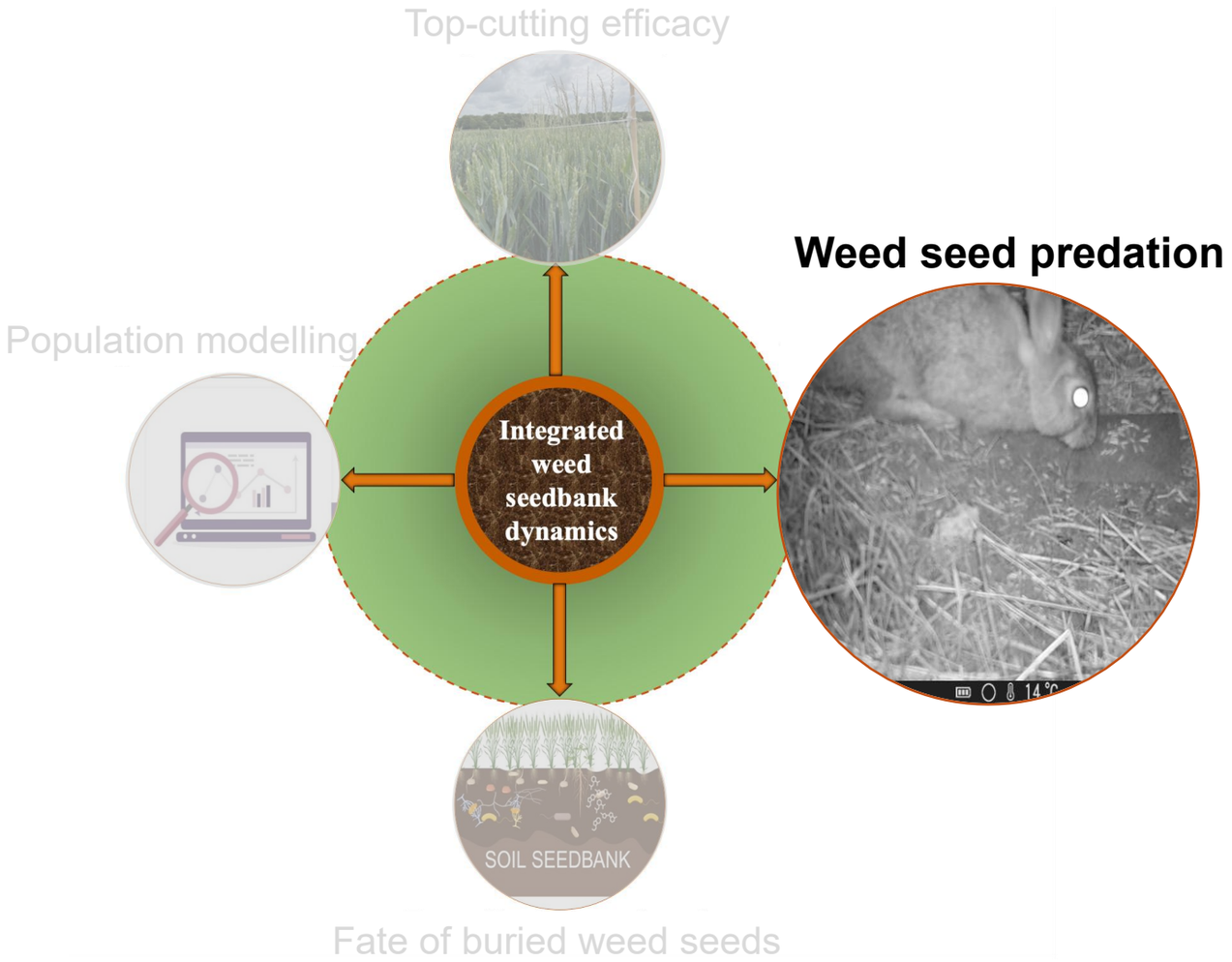
Fig. 4: Viability of seed from cut heads.

- Early cutting produced less viable seed, whereas viability increased with delayed cuts.

- Top-cutting achieved high seed head removal, but efficacy depended on species traits, canopy structure, cutting frequency and timing, and climatic conditions

(Kanomanyanga et al., 2026a)

2. How do tillage system, season, and weed species influence post-dispersal seed predation at the soil surface?



Materials and methods

1. **Study design**
   - Three species (*A. myosuroides, A. fatua, and B. secalinus*
   - Six fields (3 no-till and 3 conventional tillage)
   - Assessed across 3 seasons, repeated from 2023-2025
2. **Seed card assay**
   - Sandpaper seed cards with adhesive and a fine sand layer
   - Fixed number of seeds per species per card
3. **Two treatments**
   - Enclosed control cards (predator exclusion cages)
   - Exposed cards (accessible to predators)
4. **Field layout**
   - Transect-grid design (≥20 m from field edge)
   - Cards placed ~10 m apart across transects
   - Weekly exposure cycles (5 weeks per season)
5. **Data collected**
   - Remaining seeds per card after 1 week of exposure

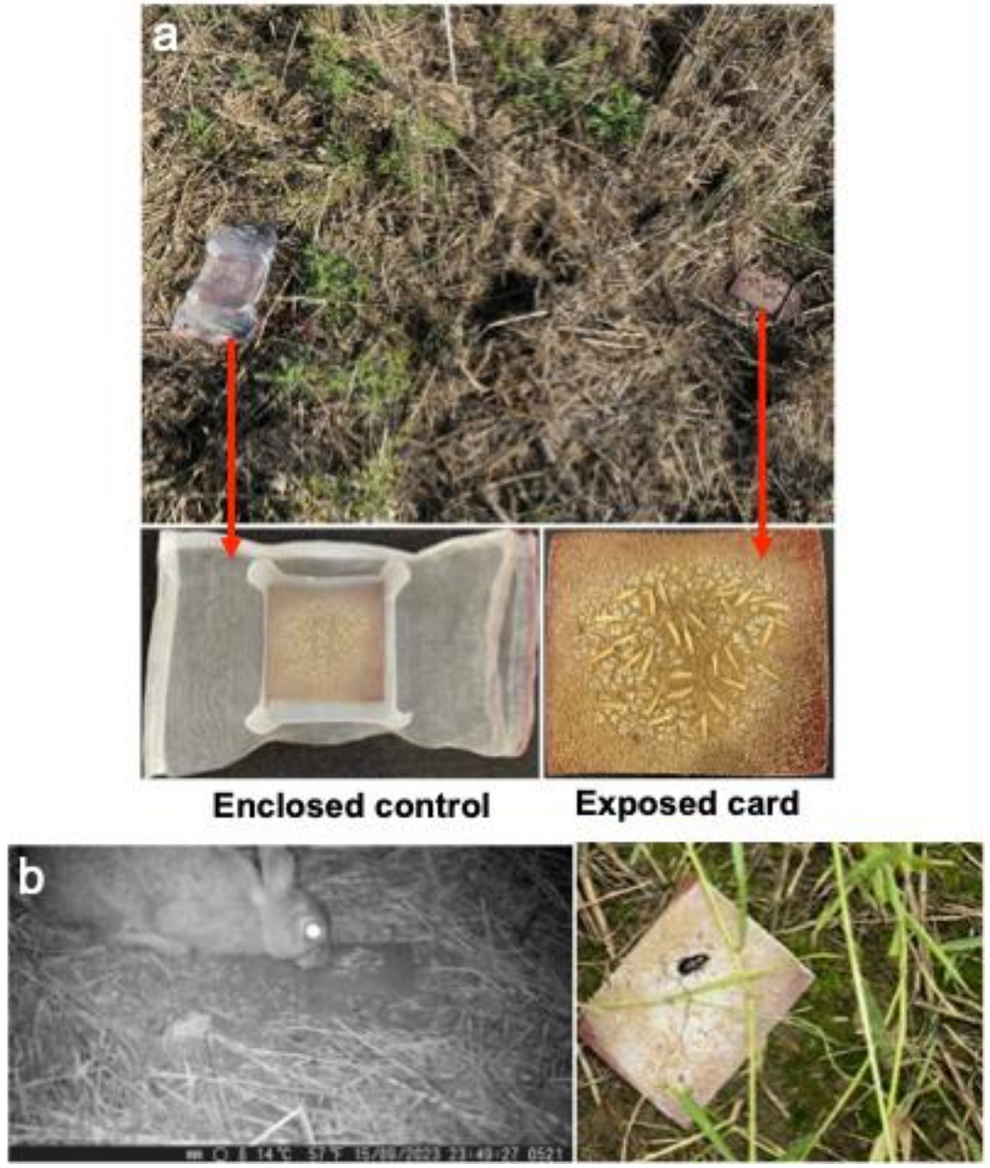
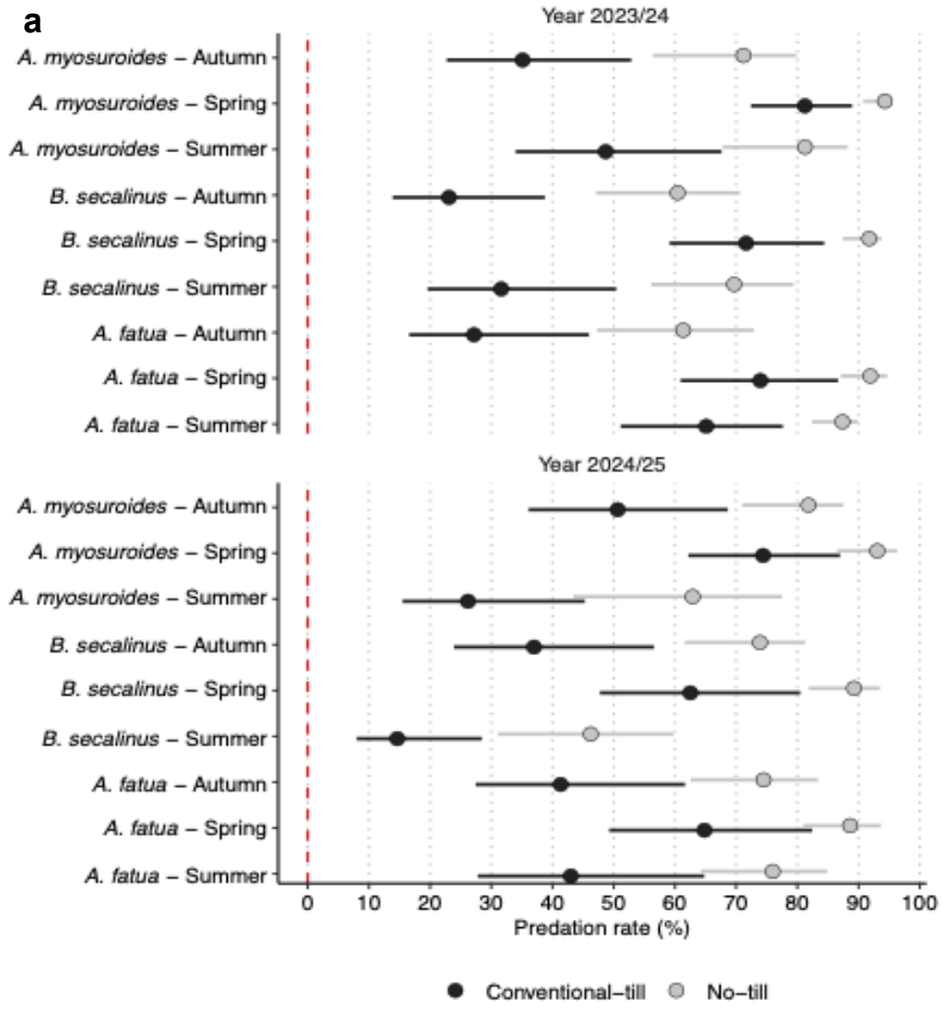
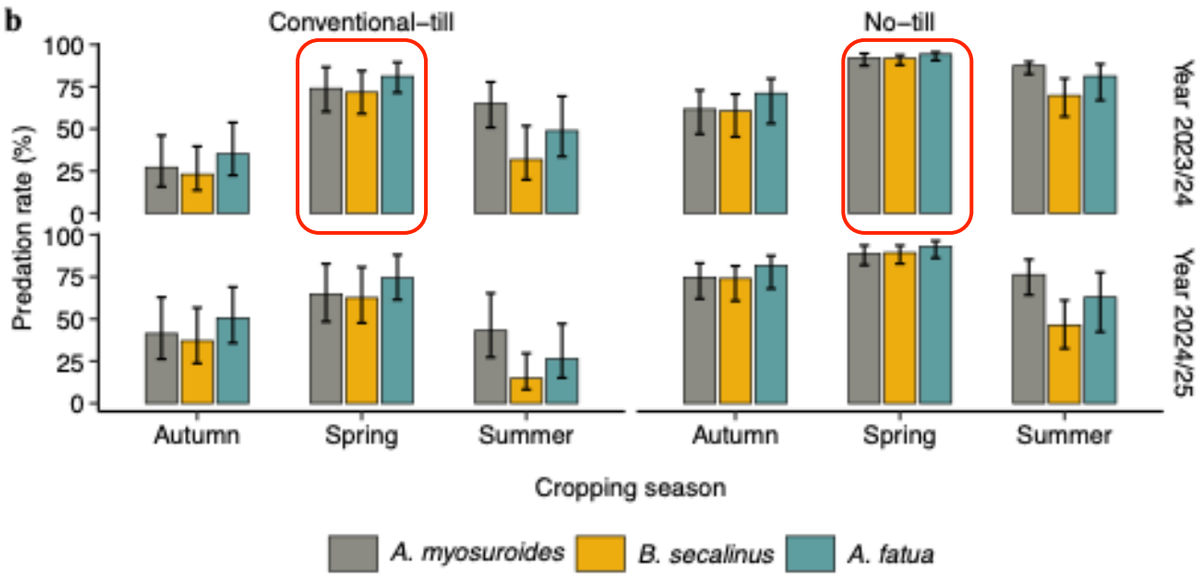


Fig. 5: Seed card field layout 9 (a) and predation evidence (b).

Results



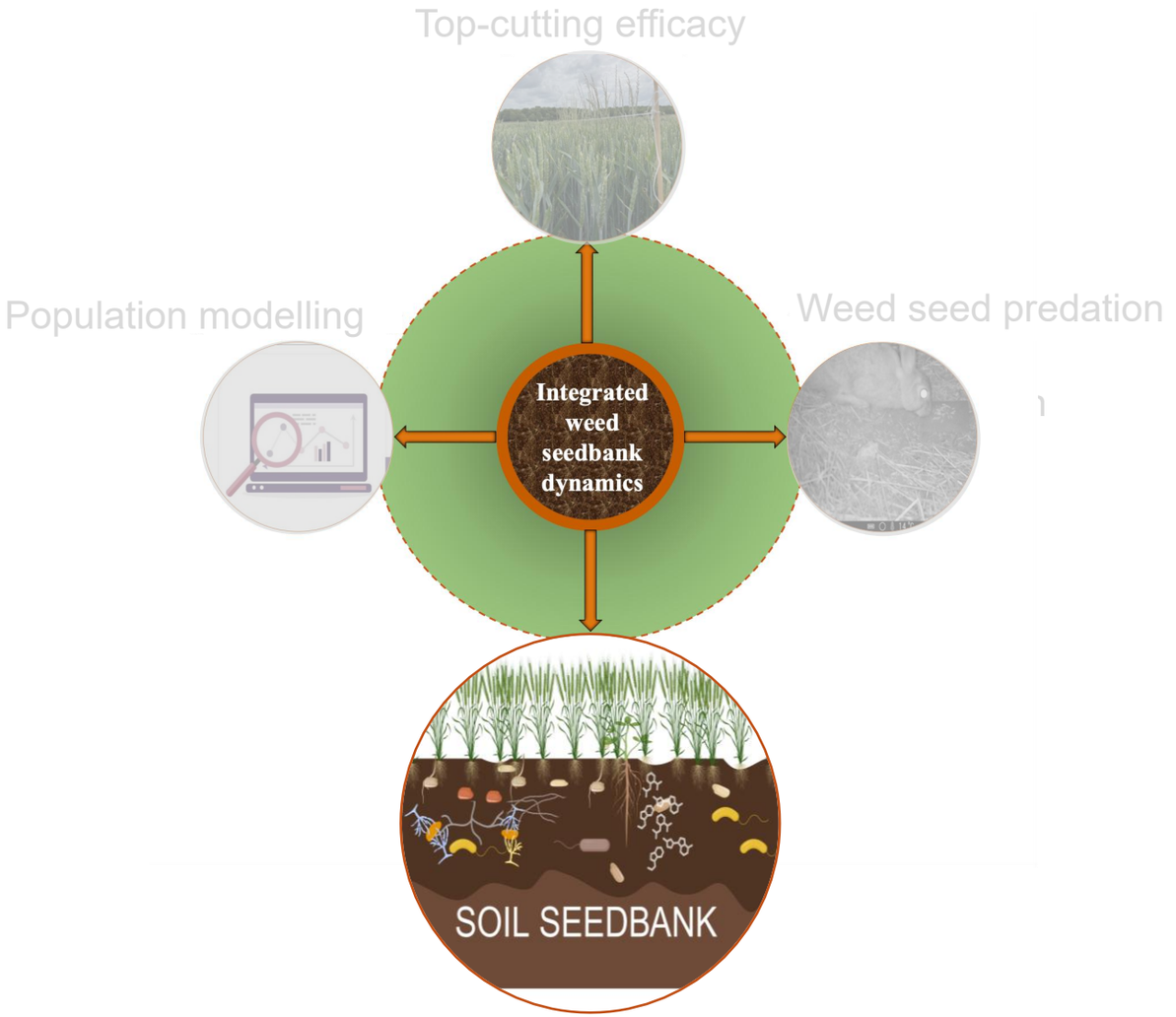


- Weekly predation was consistently higher under no-till than conventional tillage, but varied with species and season

Fig. 6: Predation rates across species (a), tillage systems and seasons (b).

(Kanomanyanga et al., 2026b)

3. How do tillage system, burial depth, and weed species affect soil-mediated seed persistence, germination, and decay?



Fate of buried weed seeds

Materials and methods

1. **Species and sites**
   - Three species (*A. myosuroides, A. fatua, and B. secalinus*
   - Six fields (3 no-till, 3 conventional tillage)

2. **Experimental design**
   - Seed burial using mesh seed bags
   - Buried at 3 depths: 0.5, 10, 20 cm
   - Retrieved at 3 time points: 3, 6, 12 months after burial

3. **Seed fate classification**
   - Field germinated
   - Persistent viable (incubator-germinated + TZ-positive)
   - Non-viable/seed mortality (TZ-negative)

   Seed viability tested through incubator **germination** and **tetrazolium** (TZ) staining

4. **Additional test**
   - Soil CO_2 efflux measured using EGM-5 CO_2 portable analyser as an estimate of biological activity

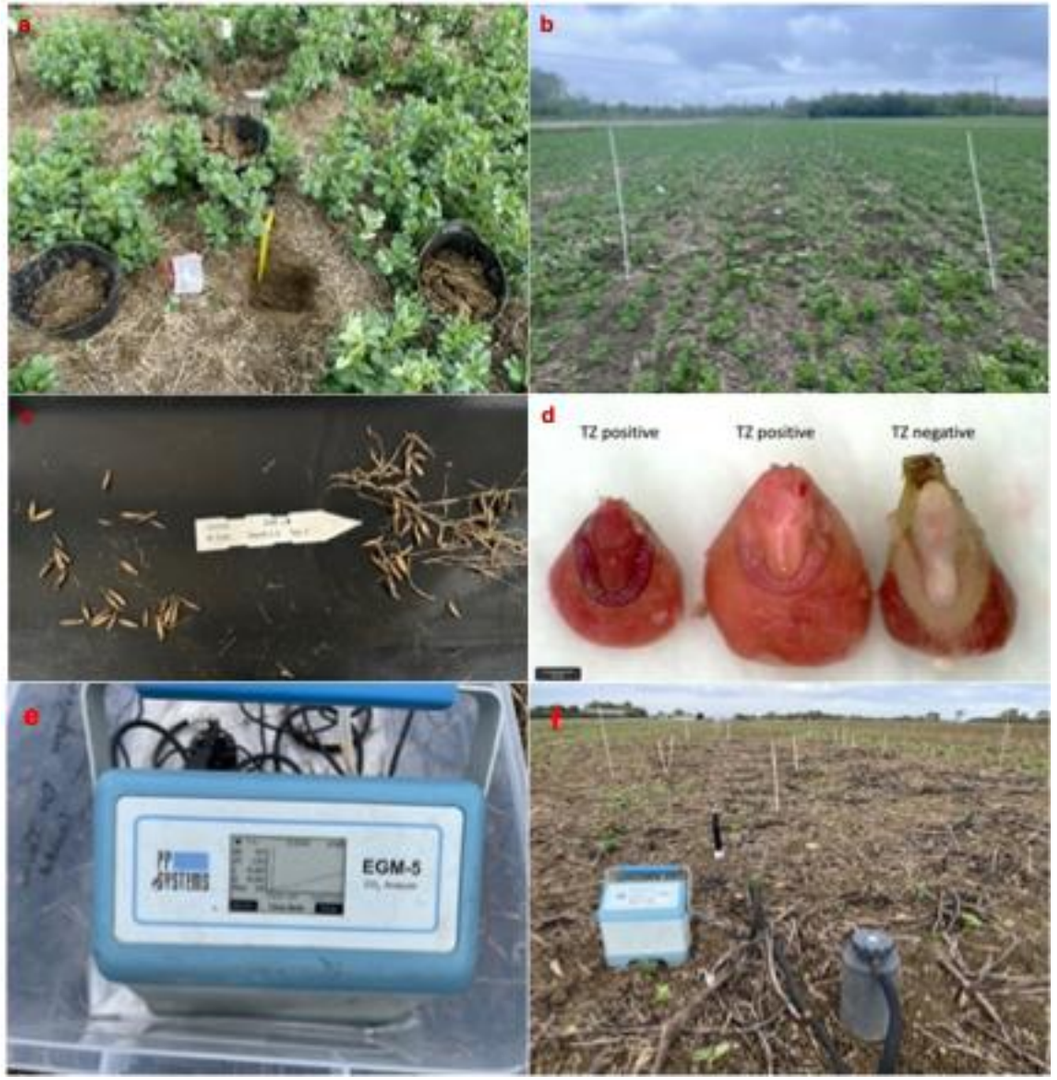


Fig. 7 Seed fate assessment (a-d) and soil biological activity estimation (e,d).

Results

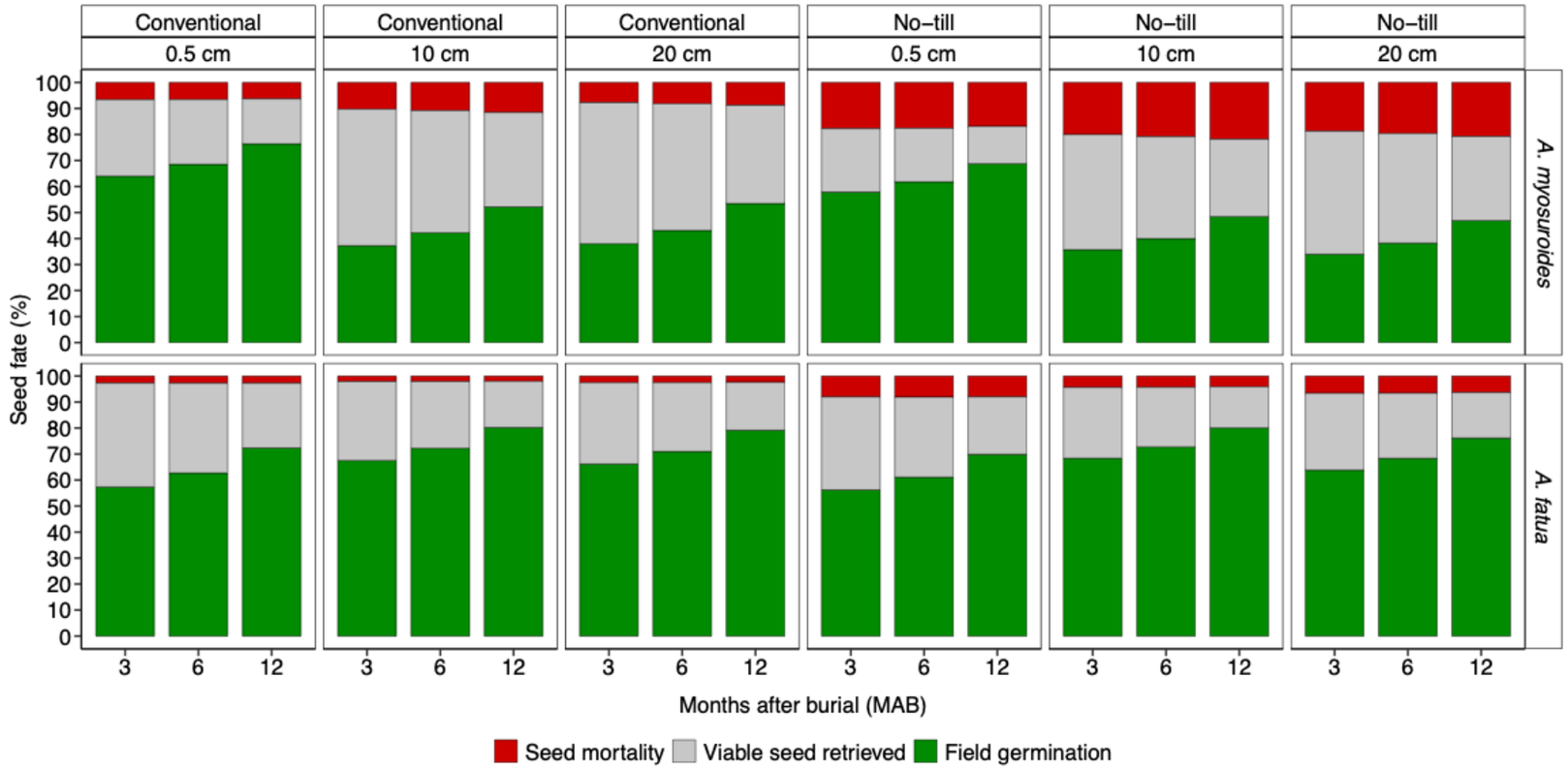
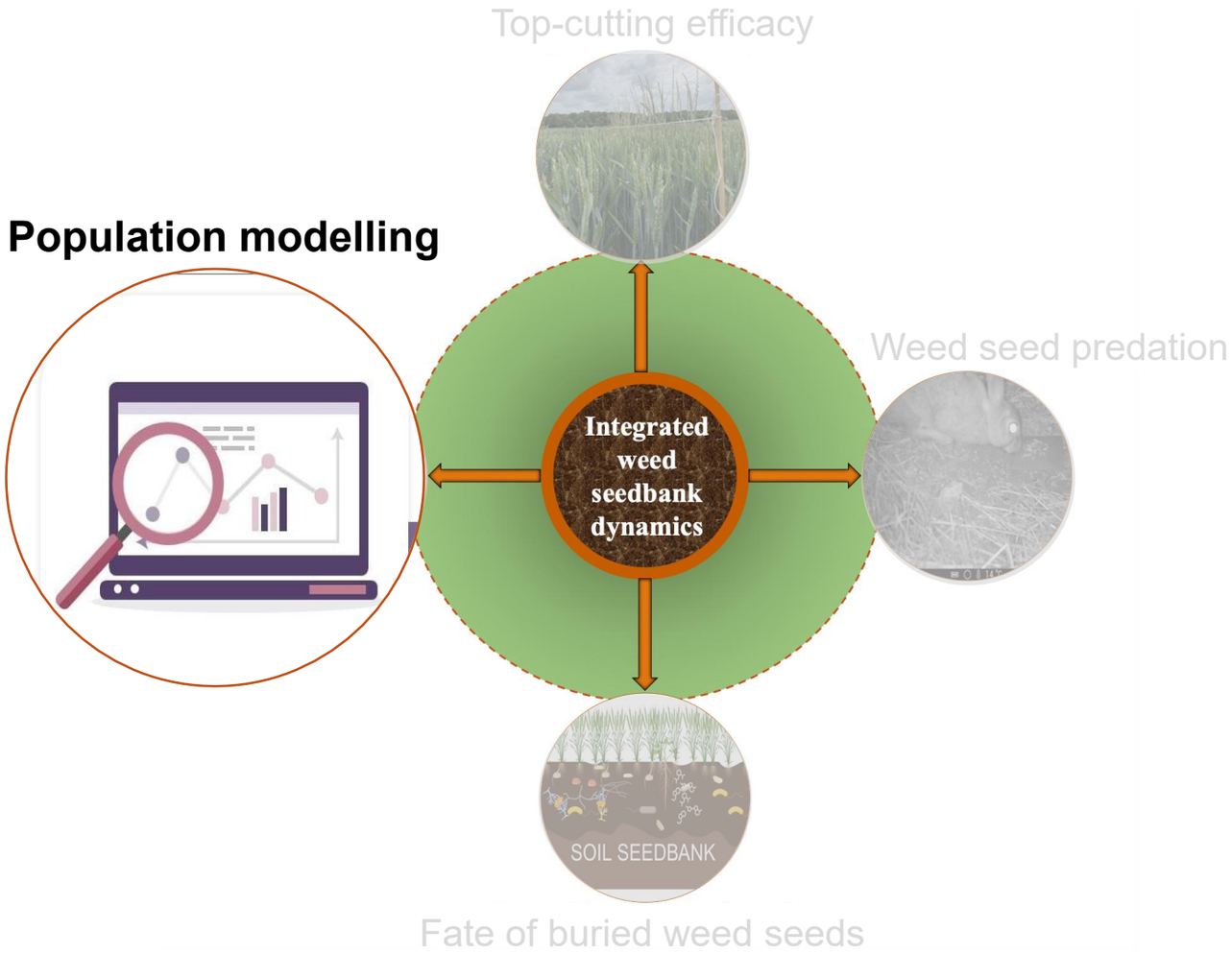


Fig. 8: Buried seed fate across species, tillage, depth, and time.

- Field germination was the dominant fate/pathway of seed loss (56- 80% across treatments)
- Seed mortality was higher under no-till (17- 22%) than under conventional tillage (6-12%, species-dependent)
- Higher seed mortality under no-till reflects enhanced soil biological activity observed across reduced-disturbance fields

4. How do seed loss pathways interact to shape long-term weed population dynamics?



Methods

1. **Model overview**
   - Stage-structured matrix population model
   - Projects population dynamics under management scenarios
2. **Parameterisation**
   - Empirical data: *predation, seed burial (decay), top-cutting*
   - Literature: *germination, mortality, fecundity*
   - Bayesian models were fitted for each process (empirical data)
   - Posterior distributions (means + uncertainty) were used as model inputs
3. **Model outputs**
   - Deterministic (λ, asymptotic) and stochastic population growth rates (λ_s, incorporating variability)
   - Sensitivity and elasticity analyses identify key demographic drivers

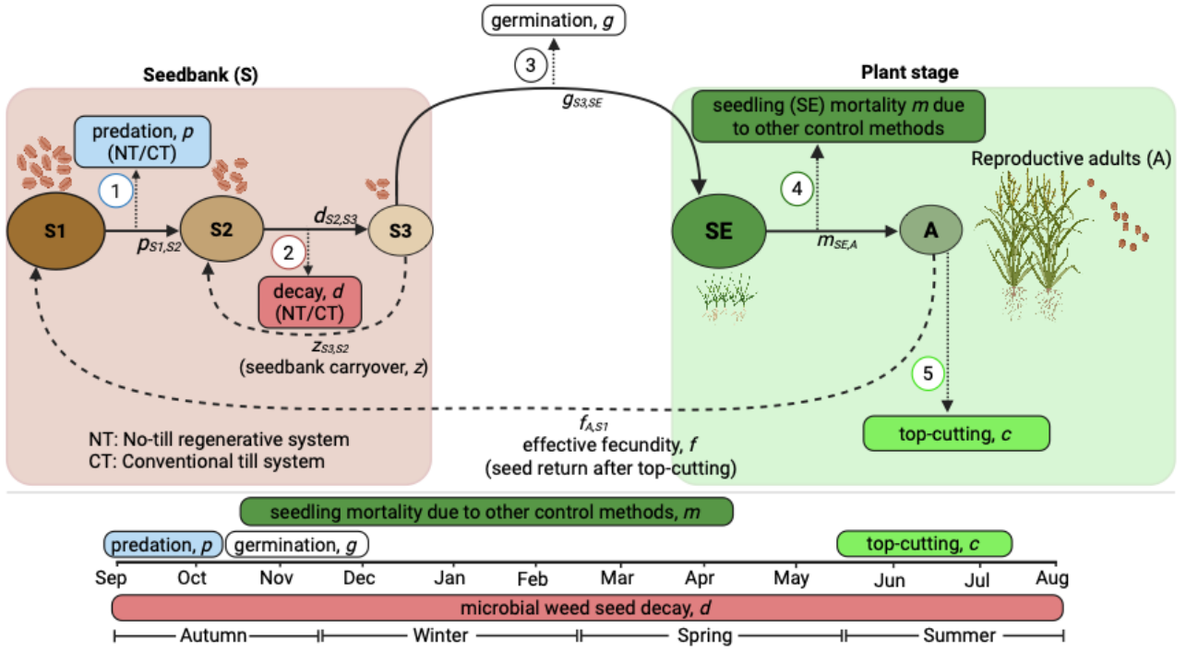


Fig. 9: Life-cycle diagram of annual grassweed population dynamics showing stage transitions and seed-loss pathways.

Results

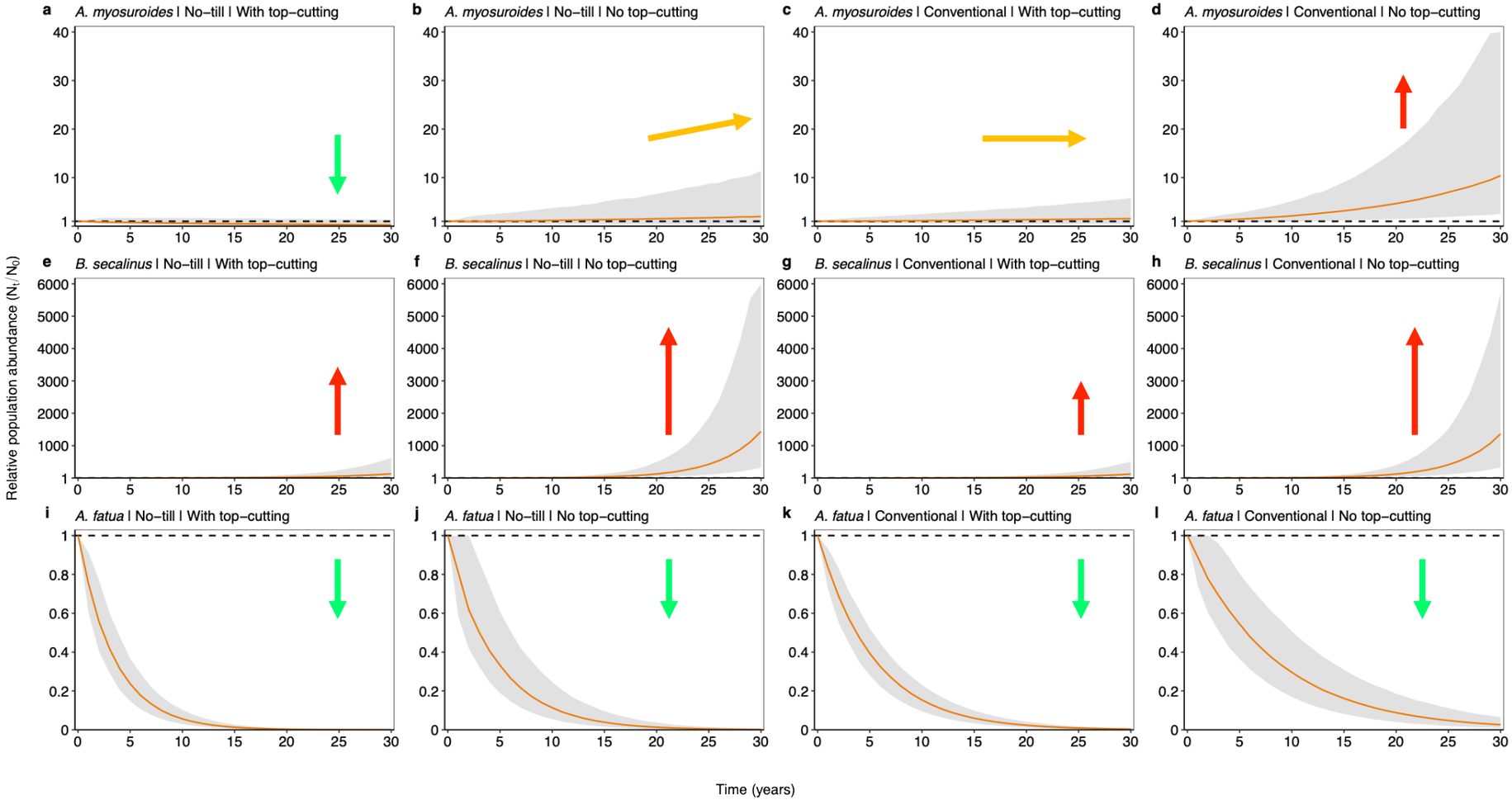


Fig. 10: Projected population trajectories under management scenarios.

- *A. myosuroides*: annual population decline of 4% under no-till with top-cutting
- *B. secalinus*: consistent population growth, increasing by 17-28% annually across scenarios
- *A. fatua*: persistent annual decline of 11-25% across management scenarios
- No-till and top-cutting were the key management drivers, with effects varying by species

(Kanomanyanga et al., under review)

Overall Conclusions and Implications

- Top-cutting, predation and decay all help reduce future weed populations by preventing seed return or increasing seed losses, although their effectiveness varies among weed species and environmental conditions
- No-till practices promote natural weed seed losses through greater seed predation and soil biological activity
- Effective weed management requires combining approaches that prevent weed seeds from entering the seedbank, increase seed losses, and control weeds at other life-cycle stages, including with herbicides.

References

Publications arising from this work

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3. Kanomanyanga, J., et al. (2026b). *Weed Science*, 66, e70084. https://doi.org/10.1111/wre.70084.
4. Kanomanyanga, J., et al. (2026c). *Agriculture, Ecosystems & Environment*, 396, 110027. https://doi.org/10.1016/j.agee.2025.110027.
5. Kanomanyanga, J., et al. (Modelling population dynamics under weed seed loss pathways; *Under review*).

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1. Buhler, D.D., et al. (1997). *Weed Science*, 45, 329-336. https://doi.org/10.1300/J144v01n01_07.
2. Menalled, F. (2008). Agriculture and Natural Resources (Weeds), 200-211. https://mssoy.org/sites/default/files/documents/weed-seed-bank-mont.pdf.

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Acknowledgements





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