

Biodiversity for mountain resilience: seeds in the landscape

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1. Introduction to Kew Science
- 2. Persistence and use of seeds in the landscape**
3. Alpine and mountain seed germination



7 July 2019

Access to seeds for landscape restoration

1. Persistence – renewal from the seed bank (ex situ and in situ)
2. Native seed production for restoration



Holly Abbandonato

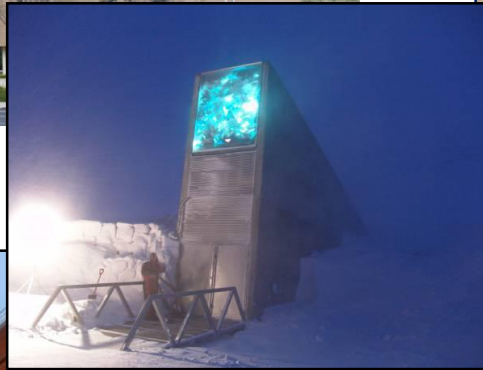


Emma Ladouceur

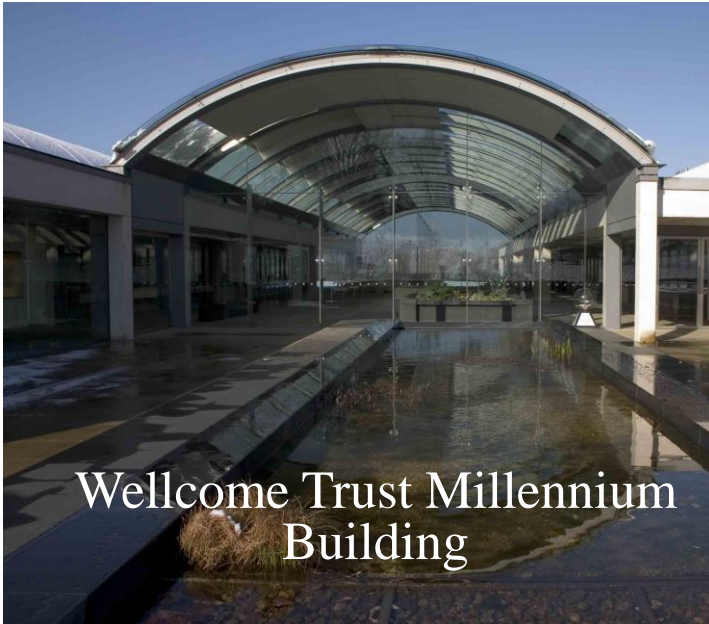


Ted Chapman

Seed banks (-20°C)



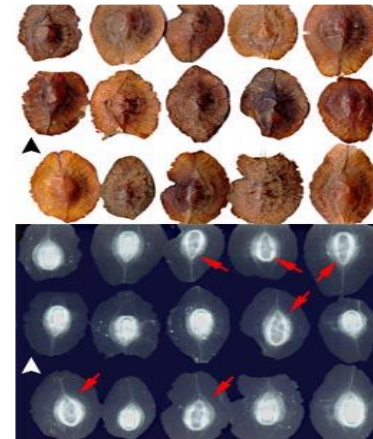
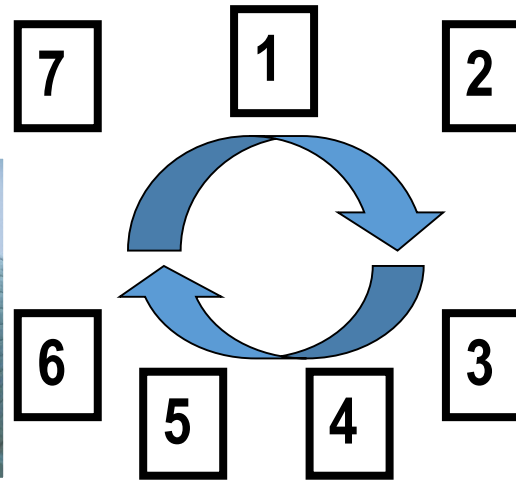
Millennium Seed Bank Partnership



- **Funding:** £75m from U.K. Lottery, government, corporate & private sponsors
- **Phase 1 (1997-2000):** Collect U.K. native flora and build WTMB and MSB
- **Phase 2 (2000-2010):** Conserve 10 % world flora (24,200 species)
- **Phase 3 (to 2020):** Conserve another 45,000 species

Seed Banking

1. Collect
2. Dry
3. Clean
4. Purity
5. Package
6. Storage
7. Germinate



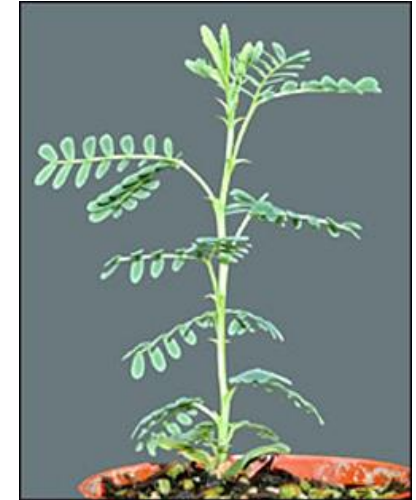
Seed storage > 100 years

6



A species of *Leucospermum* germinated from seed that was over 200 years old.

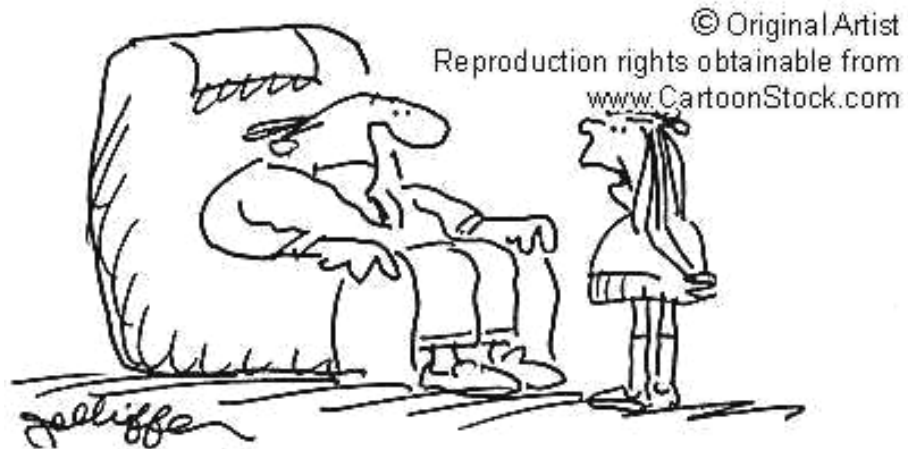
Leucospermum



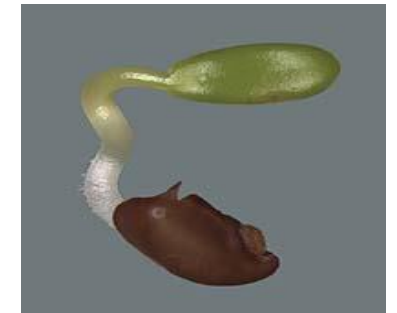
Acacia



Daws et al (2007)



"Don't worry if you can't remember your age grandad, we'll get you carbon dated!"



Lipparia

Persistence: seed > 100 years old

Species	Lifespan	
<i>Canna compacta</i>	600 years;	germination
<i>Nelumbo nucifera</i> (sacred lotus)	466 years;	slightly abnormal
	plant (1288 years, but plant died)	
<i>Malva parviflora</i> , <i>Hordeum leporinum</i> , <i>Medicago polymorpha</i>	200 years;	germination
<i>Melilotus indica</i> , <i>Chenopodium murale</i>	183 years;	germination
<i>Albizzia julibrissin</i>	147 years;	germination
<i>Chenopodium album</i> (fat hen)	143 years;	germination
<i>Verbascum blattaria</i> (moth mullein)	120 years;	plantlets
<i>Hordeum vulgare</i> , <i>Avena fatua</i>	110 - 124 years;	germination

Dr Beal's buried seed experiment after 120 years



Verbascum blattaria
(moth mullein; *Scrophulariaceae*)
<https://www.rhs.org.uk/Plants/22617/Verbascum-blattaria/Details>



Frank Telewski, curator of Beal Botanical Garden, with the results of an experiment started in 1879

Ancient palm seeds



David Blumenfeld / Special to The Chronicle

Researchers Elaine Solowey (left) and Sarah Sallon show off seedling, whose DNA is being studied. San Francisco Chronicle (12 June 2005)



David Blumenfeld / Special to The Chronicle



Chronicle Graphic

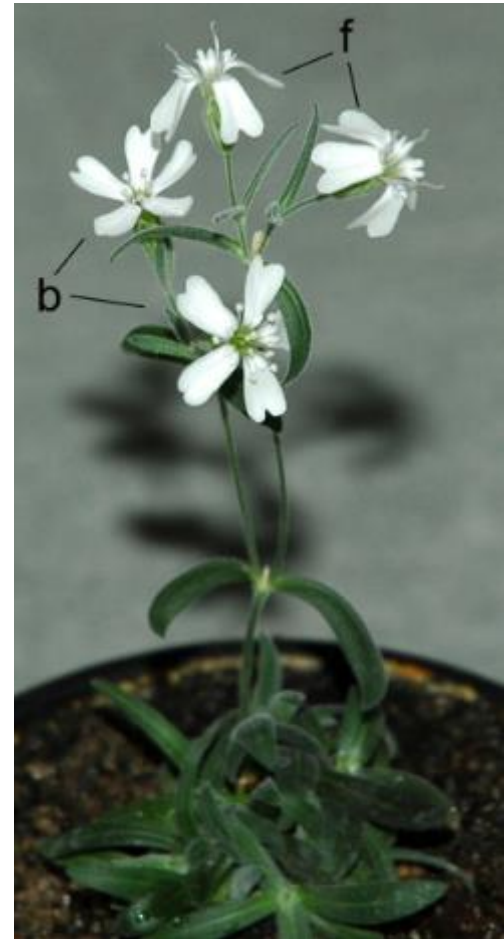
Are seed tissues immortal?

Survival after 32000 years (-7°C)

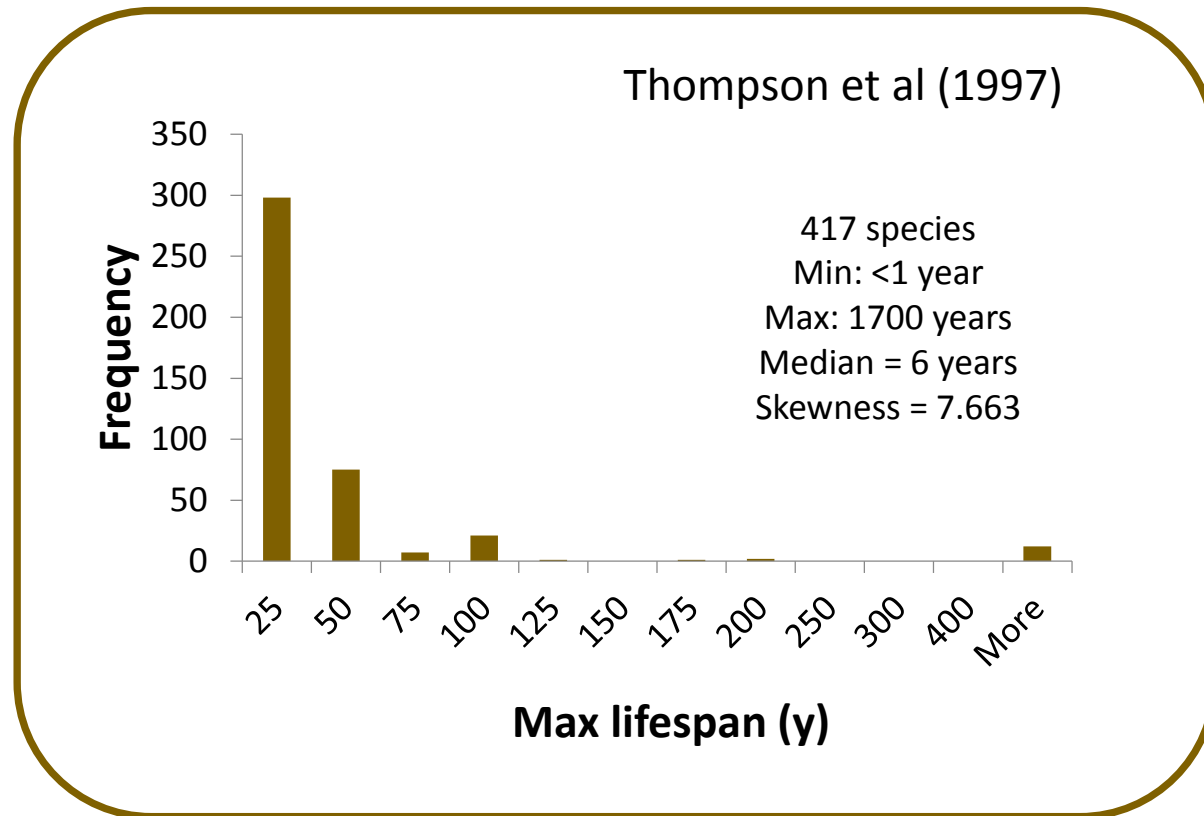


***Silene stenophylla*: grown *in vitro*
from placental tissue**

Yashina et al., 2012; PNAS)



Seed persistence in soil in temperate areas



Thompson K, Bakker JP, Bekker RM. 1997. *The soil seed banks of North West Europe: methodology, density and longevity*: Cambridge University Press.

Persistence above ground (aerial SB)

Fraxinus excelsior



[http://www.bioimages.org.uk/
HTML/P150292.HTM](http://www.bioimages.org.uk/HTML/P150292.HTM)

Banksia oblongifolia



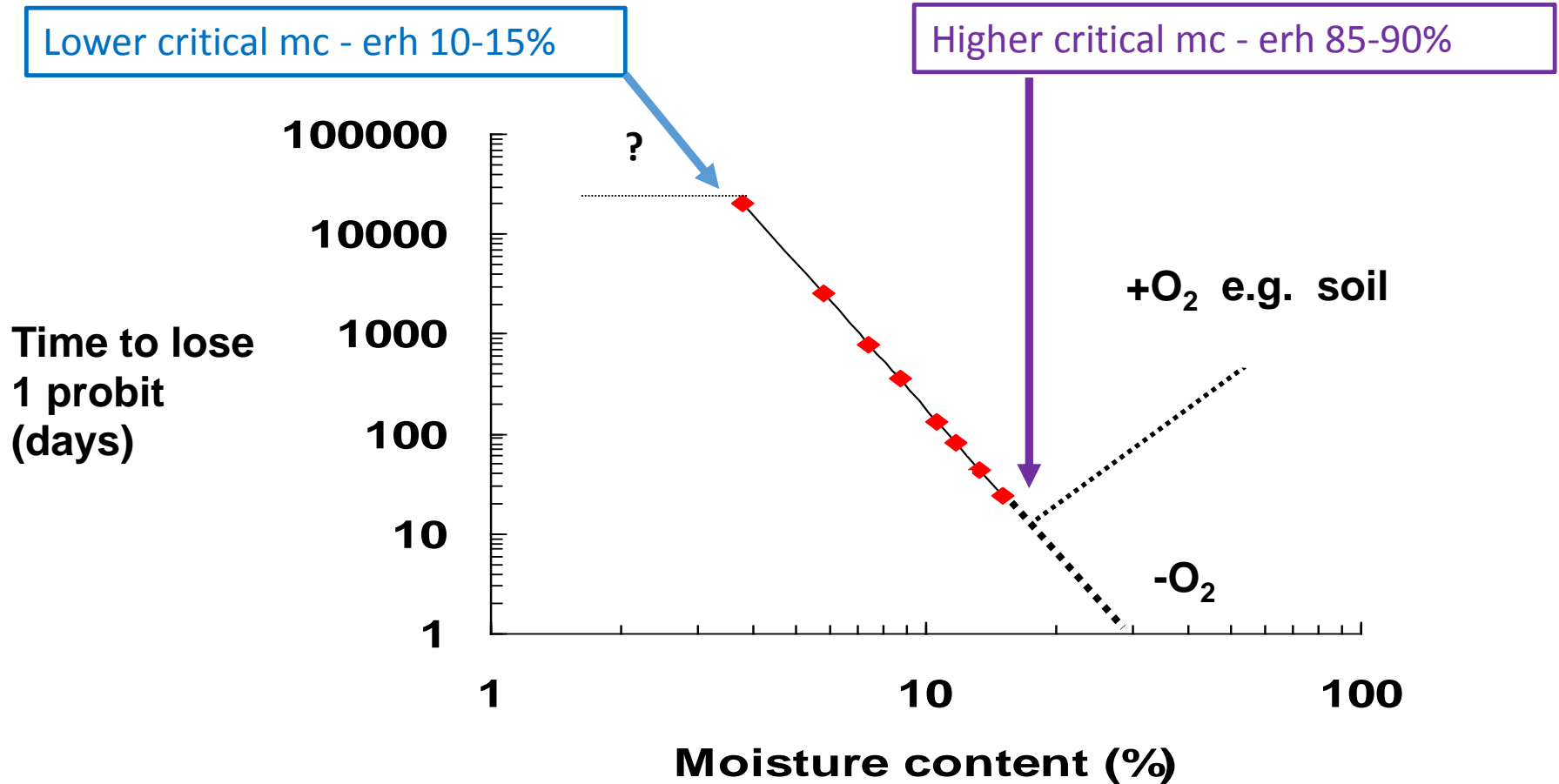
anpsa.org.au

Soil seed banks (persistence and mass)



Species	Common name	Mass (mg)	Seed bank density m⁻²
<i>Avena fatua</i>	wild oat	22.2	79
<i>Galium aparine</i>	goose grass / cleavers	6.74	108
<i>Galeopsis bifida</i>	bifid hemp-nettle	3.45	196
<i>Lamium amplexicaule</i>	henbit dead-nettle	0.61	340
<i>Verbascum thapsus</i>	great mullein	0.09	449

Moisture relations of seed longevity for yellow maize



Summary:

1. Majority of species produce seeds that survive drying, and can be banked *ex situ*;
2. Seed also survive *in situ* for many years;
3. Both forms of persisting seeds can be the source of landscape recovery / restoration.



Restore 350 million ha of land by 2030



Trends in pressure on ecosystems

Ecosystem type	Habitat change	Climate change	Over-exploitation	Invasive species	Pollution and nutrient enrichment
Urban	↗	↑	↗	↗	↑
Cropland	↗	↑	↗	↗	↑
Grassland	↗	↑	↗	↗	↑
Woodland and forest	↘	↑	→	→	↗
Heathland, shrub and sparsely vegetated land	→	↑	→	↗	↗
Wetlands	→	↑	→	↗	↘
Freshwater (rivers and lakes)	→	↑	→	↗	↘
Marine (transitional and marine waters, combined)*	↗	↑	→	↗	→

EU Biodiversity Strategy

Ecosystems
under pressure

Kew's response to the Bonn Challenge

- 1) Seed Biodiversity Research:**
NASSTEC: native seed science and use for plant conservation and grassland restoration in Europe.
- 2) Seed Production:** UK Native Seed Hub.



1) NASSTEC (2014-18):

native seed science and use for plant conservation and
grassland restoration in Europe

the **NA**tive Seed Science
Technology and
Conservation

is

a Marie Curie Initial
Training Network (ITN)
funded under FP7

(1.4.2014 – 31.3.2018)

PITN-GA-3013-607785)



**Costantino Bonomi, MUSE,
Science Museum, Trento, Italy**



NASSTEC

Initial Training Network

- Funds: 3.3 million Euros
- 4 years (1.4.2014-31.3.2018)
- Training 11 ESR + 1 ER in a cross-cutting European training programme
- 7 network training events: 4 workshops, 2 summer schools and a **final conference in Kew in 2017 open to the public**



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EDITORIAL

Maximising the use of native seeds in restoration projects

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Scientific objectives

OVERALL AIM: To create a functioning network of academic and industry specialists able to produce and use European native seed effectively and efficiently.

OBJECTIVES:

1. Deliver **scientific and practical training** to ESRs and partners to ensure high quality seed sourcing and production.
2. **Connect key disciplines** in native seed use, from innovative seed science research to technological development **and inter-sectoral links**.
3. **Develop joint network products**, including assessment and evaluation tools, such as protocols, and research outputs collated in a '**NASSTEC Manual**' for relevant internal and external stakeholders.
4. **Provide draft guidelines** on the **production and use of native seed** for submission to EU regulatory services as a complement to available seed certification schemes.
5. **Connect NASSTEC** with 'best practice' in USA and Australia.

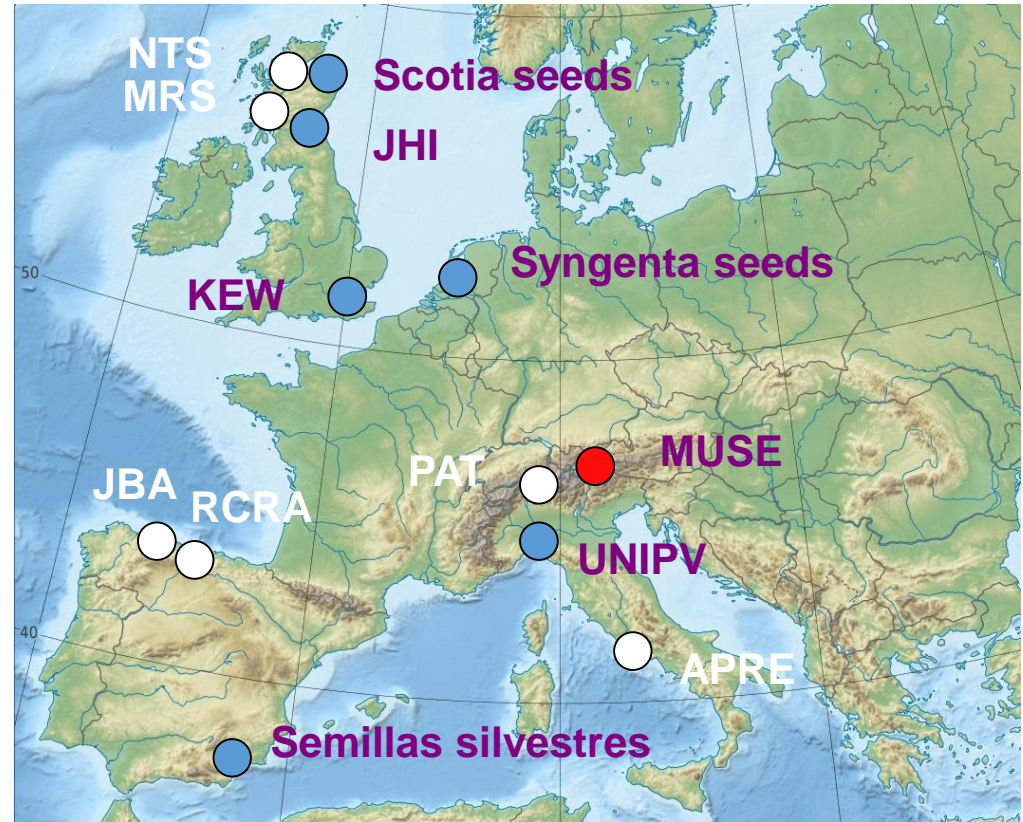
NASSTEC: The partnership

**7 full partners in 4 countries
(Italy, UK, Spain, The Netherlands)**

- 4 academic institutions:
MUSE, UNIPV, JHI, KEW
- 3 native seed companies
(Scotia Seeds, Semillas Silvestres, Syngenta seeds)

7 associated partners:

- RCRA, MRS, APRE, NTS,
BGPA, JBA, PAT



NASSTEC: The need

- Native seeds are needed in Europe for a wide range of grassland restoration: roadworks, ski slopes etc.
- **Yet no native seeds are widely available in Europe**
- Market underdeveloped only small scale operations, detached from academic sector
- **Lacking baseline knowledge on key species**



NASSTEC: The aims

NASSTEC plans to meet these needs by delivering:

- well trained human resources to support industries and develop new companies
- **bridge academia and industry delivering key information where needed with project manuals**
- key link with developed markets in US & Australia
- **demonstrative pilot projects for grassland restoration in 4 EU bio-geographical areas**



Training

AIM: deliver on-the-job training, exchange visits and secondments (2 per year), network events, and sharing the findings of NASSTEC at the final conference.

Impact: increased human capital and improved competitiveness of a sustainable and dynamic European native seed industry.



Science programme structure

12 research topics, clustered under three sub programmes:

A. *In situ* seed sampling -

ESR 1A ,2A ,3A - To provide essential training in plant taxonomy, ecology and reproductive plant biology, **enabling the selection of species for mitigation projects** aimed at Alpine, Atlantic, Continental and Mediterranean grassland habitats

B. Seed biology characterisation -

ESR 4B, 5B, 6B, 7B - To develop **skills in native seed physiology** (germination and storage) and **stress tolerance**, so that functional and genetic **data** can be generated and **used to match seed lots to specific environments for improvement**

C. Production and deployment of seed.

ESR 8C, 9C, 10C, 11C - To **transfer knowledge** on the means of improving seed quality (performance) **to SMEs for native seed production**, enhancing the conversion rate from seed to plant (increased efficiency)

ER12 – Transfer of NASSTEC knowledge to European Seed Producers

Three Work Programmes



A: *In situ* seed sampling

ESR1: Biogeog. + sp choice
ESR2: Traits-based selection
ESR3: Seed phenomics

B: Seed biology characterisation

ESR4: Alpine seed dorm.
ESR5: Grassland sp.
propagation.
ESR6: Alpine seed longev.
ESR7: Infra-sp variation

C: Seed production and deployment

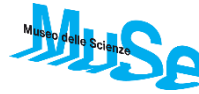
ESR8: Seed production
ESR9: Woodland herbs
ESR10: Priming
ESR11: Certification
ER12: Comms

4 research institutes: Kew, JHI, Univ Pavia, Museo-Trento

3 companies: Scotia Seeds, Syngenta, Semillas Silvestres

+ Scientific Advisory Board

Training



11 ESR + 1 ER



Kew Supervisory Team:

Peter Toorop
Louise Colville
HW Pritchard



Royal Botanic Gardens
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Kew

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Kew

Training

Secondments & Exchange visits

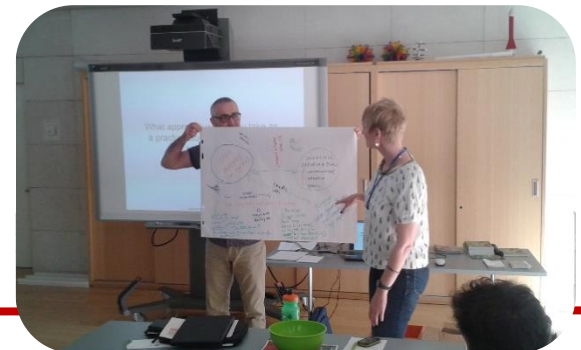


Summer Schools:

1. Seed collection
2. Seed germination

Workshops

1. Molecular diversity
2. IPR and patenting
3. Education and outreach
4. Industrial seed production



NASSTEC findings: seed sources



...a coherent ecological
network

Seed availability: 1123 species

Focus: grasslands of conservation concern;

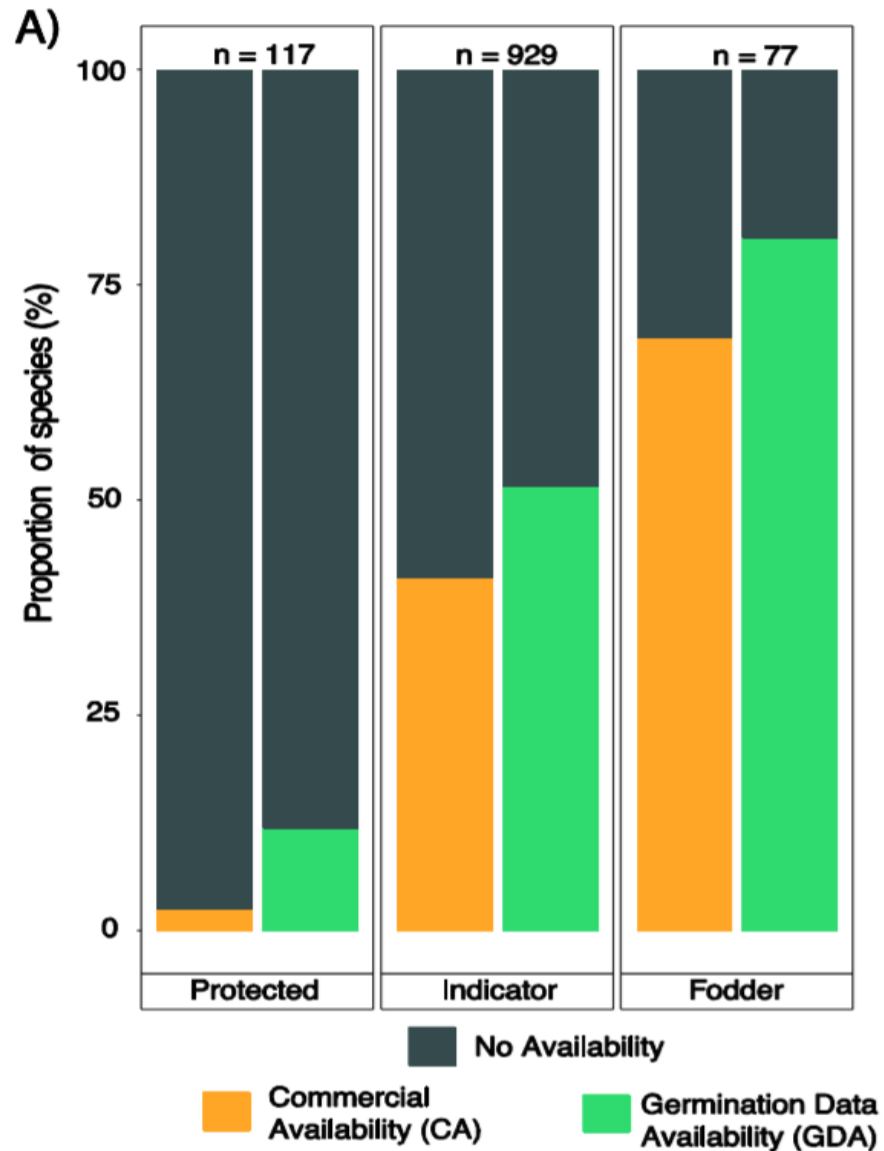
Main supplier of native seed in 17 countries across Europe:

1) seeds commercially;

OR

2) seed Germination Data

Ladouceur et al (2018)
Conservation Letters



Germination information sources

Seed Information Database

Search the Seed Information Database

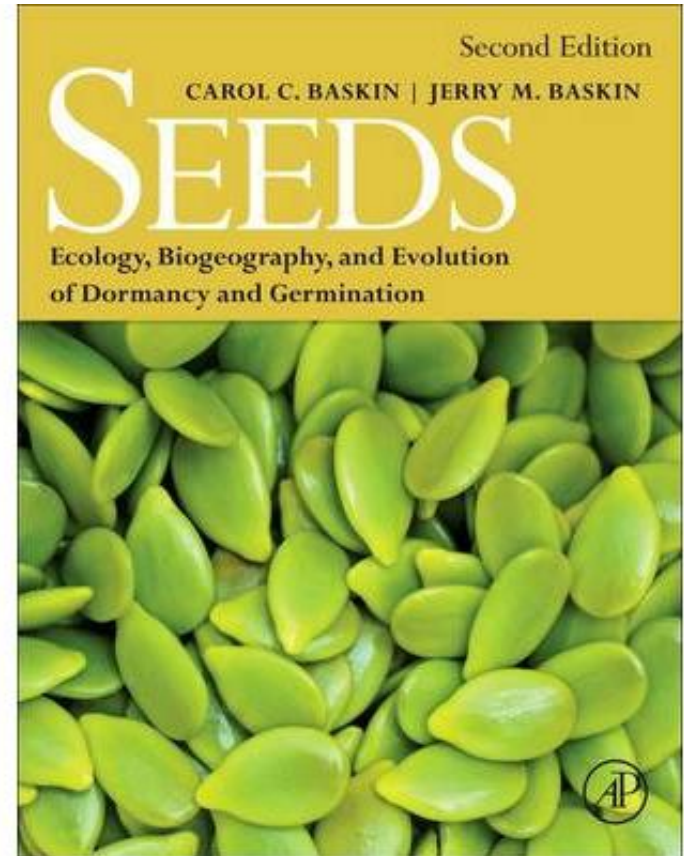
(release 1.1, May 2000)

SID is a compilation of seed biological trait data from the MSBP's own collections and from other published and unpublished sources. Its primary purpose is as an internal source of a variety of seed biological information; for use in large scale analysis and decision support for seed conservation operations.

Citing SID

Search the Seed Information Database			
APG Clade	<input type="text"/>		
APG Order	<input type="text"/>		
Family	<input type="text"/>		
Genus	<input type="text"/>		
Species	<input type="text"/>		
Storage Behaviour	<input type="text" value="(All)"/>		
Only find records with data on:			
<input type="checkbox"/> Storage Behaviour	<input type="checkbox"/> Weight	<input type="checkbox"/> Dispersal	<input type="checkbox"/> Germination
<input type="checkbox"/> Oil Content	<input type="checkbox"/> Protein Content	<input type="checkbox"/> Morphology	<input type="checkbox"/> Salt Tolerance
<input type="button" value="Reset"/> <input type="button" value="Search"/>			

Seed information database:
Kew



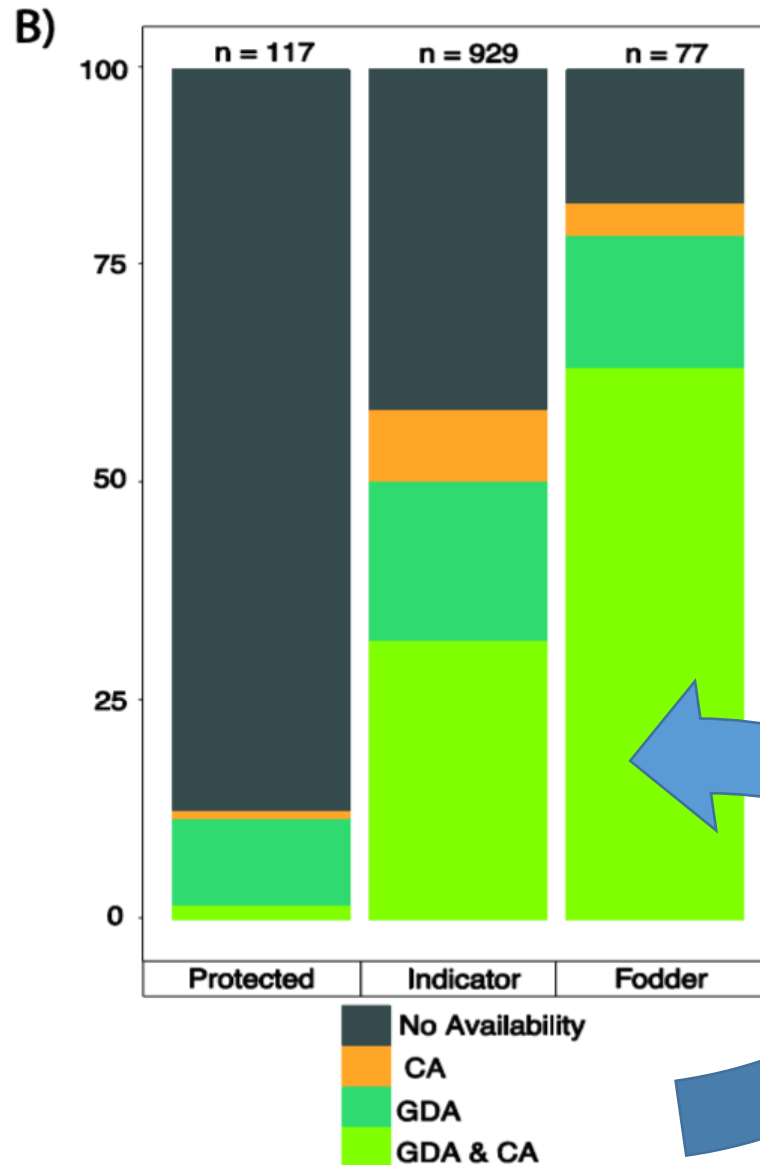
Seeds (2014) by Carol and
Jerry Baskin

Seed availability: 1123 species

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- 1) seeds commercially;
- AND**
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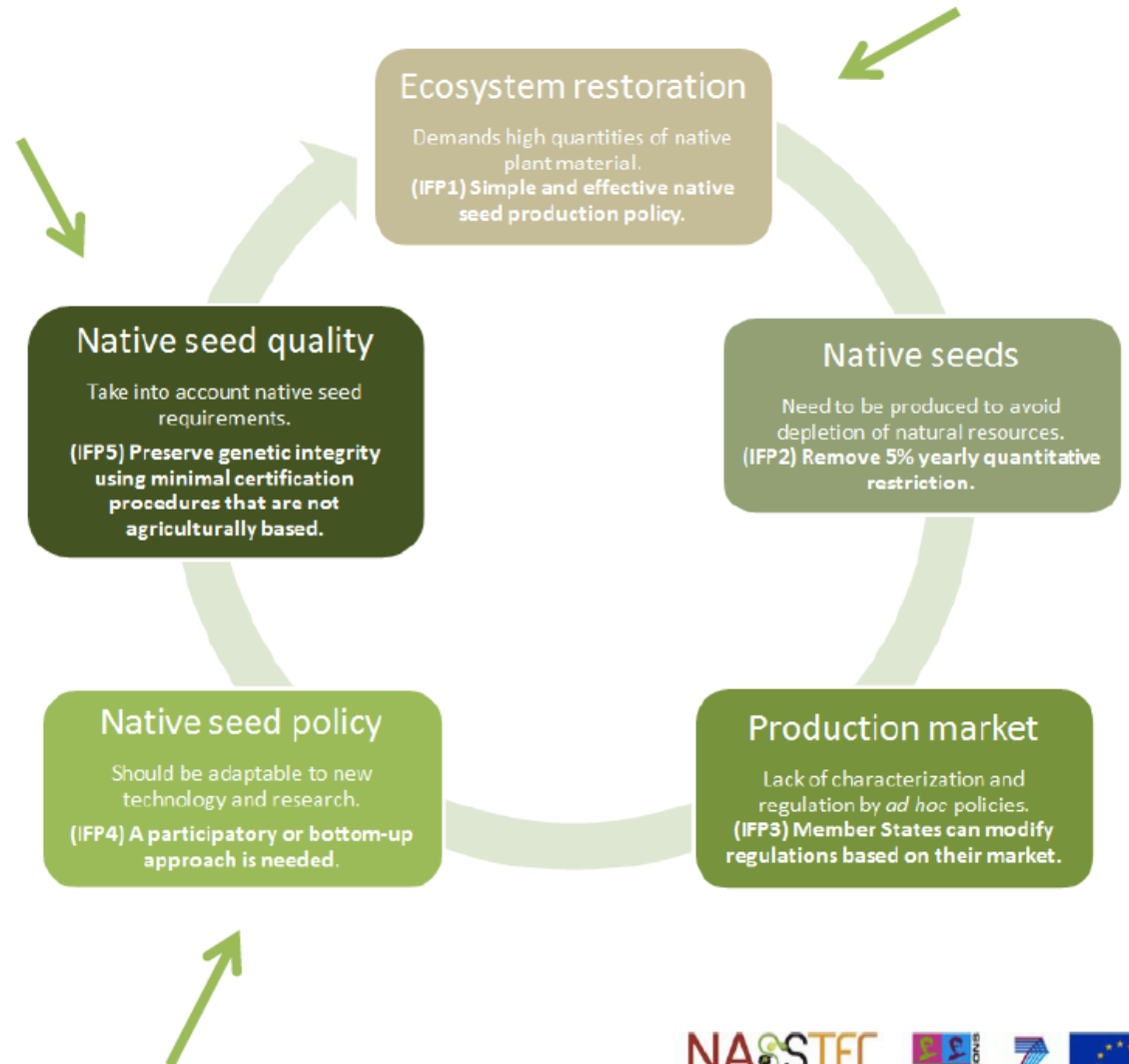


Findings: seed sources

In Europe..

there is no policy written strictly for native seed production except as fodder or animal feed.

Abbandonato et al.
(2018) Restoration Ecology

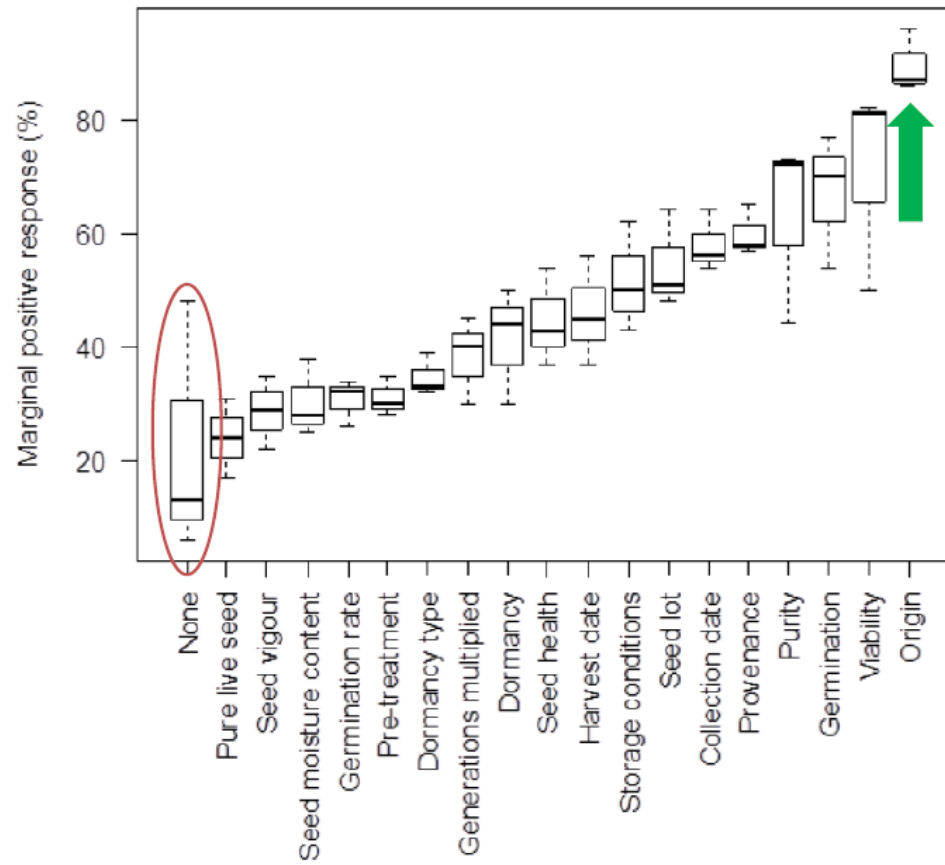


Findings: seed quality attributes

Participants

Land (n=54)
Research (n=89)
Trade (n=50)

-Categorical multi-response data
-Multiple marginal independence (MMI) test using a Bonferroni post hoc



Abbandonato et al.
(2018) Restoration
Ecology

Quality assurance of seeds (UK Seed Hub)



- Verify provenance of supplied seed;
- Test viability of supplied seed;
- Purity guarantee;
- Engage with 20,000 schools.



Outcome of NASSTEC: European Native Seed Producers Association



Society for Ecological Restoration:
International Network for Seed-based
Restoration

2) Seed Production: UK Seed Hub

- Aims to enhance the resilience and coherence of the UK's ecological network by increasing the quality and diversity of native plant materials available for conservation and habitat restoration;
- 2011-2018 UKNSH provided plant materials and technical assistance to 57 projects, working with 36 organisations;
- Regenerated 44 species.



Natural Regeneration

- + Low cost
- + Maximises potential for local adaptation
- + Eliminates risks associated with non-local seed
- May be slow
- May require disturbance to create germination niches
- Fragmentation limits opportunities for natural colonisation
- **Soil seed banks not necessarily representative of target vegetation**



Species Selection

Area 1 – Bolney Substation

General Notes

Access	Level access for pedestrians and machinery through gate from Wineham Lane. The field between the gate and harvesting site will be cropped for silage and grazed. Access for hand harvesting is permitted with 48 hours notification to RSK at any time. Machinery should not cross this field whilst it is being cut for silage.
Grazing control	Livestock will be excluded from the harvesting site until harvesting is complete. RBG Kew will inform RSK as soon as harvesting is complete to allow the site to be topped.
Minimum seed requirement	2ha of affected grassland @ 2kg/ha = 4kg of seed Target minimum: 6kg
Notes	Targets for harvesting have been drawn from the unimproved grassland surveyed and observed by RSK around target note 277L. <i>Goudinia fragilis</i> was observed in the sward in May 2014, with verification by herbarium staff at RBG Kew. This is an uncommon species in Sussex and is included as a target.

Brush Harvesting

Harvest #	W/commencing	Harvest Area	Target species
RSK14-B-1/1	14 th July	A strip running NW to SE across Area 1.	<i>Anthoxanthum odoratum</i> , <i>Trisetum flavescens</i> , <i>Goudinia fragilis</i> , <i>Festuca rubra</i> , <i>Cynosurus cristatus</i> , <i>Briza media</i> , <i>Poa pratensis</i> , <i>Ranunculus acris</i> , <i>Rumex acetosa</i> , <i>Carex flacca</i> .
RSK14-B-1/2	4 th August	Adjacent to the strip harvested above.	<i>Agrostis</i> spp., <i>Trifolium pratense</i> , <i>Phleum bertolonii</i> , <i>Lotus corniculatus</i> , <i>Cerastium fontanum</i> , <i>Centaurea nigra</i>

Hand Harvesting

Species	Approximate timing	Notes
<i>Luzula campestris</i>	Late May	Early
<i>Cardamine pratensis</i>	Early Jun	Early
<i>Ajuga reptans</i>	Early/mid Jun	Early
<i>Ranunculus bulbosus</i>	Mid-late Jun	Early
<i>Anacamptis morio</i>	Late Jun	Early
<i>Rumex acetosa</i>	Mid July/early Aug	Supplement brush harvest
<i>Goudinia fragilis</i>	July	Supplement brush harvest
<i>Lotus corniculatus</i>	Aug/Sept	Supplement brush harvest
<i>Agrostis</i> spp.	Aug/Sept	If not mature or absent in August brush harvest
<i>Prunella vulgaris</i>	Aug/Sept	If not mature or absent in August brush harvest
<i>Cerastium fontanum</i>	Aug to Oct	Supplement brush harvest

1. Species drawn from reference system

2. Framework species

- Fast coverage
- Promote future natural or assisted regeneration

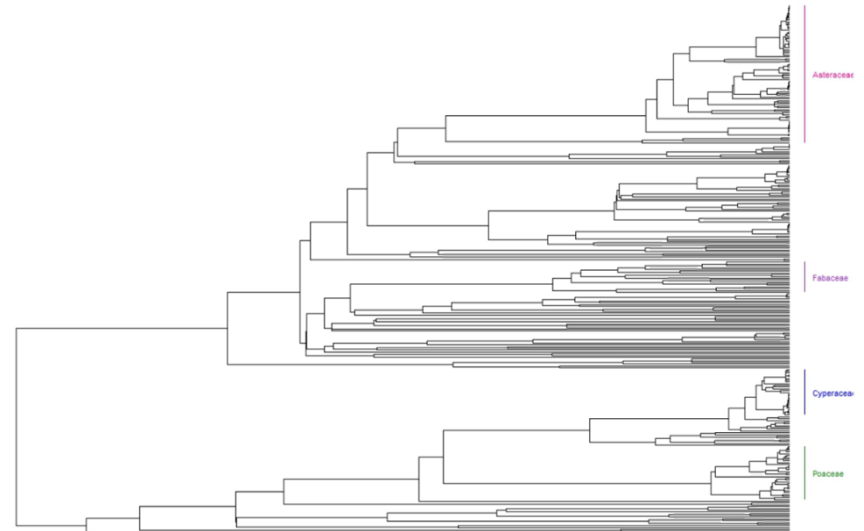
3. Rare and distinctive species

- Consider specialist establishment needs

Prairie Restoration

(Kayri Havens)

- Diversity, but...
 - Species diversity
 - Genetic diversity
 - Phenological diversity
 - Functional trait diversity
 - **Phylogenetic diversity**



Commercial Seed

- + Cost effective
 - + Available in quantity, on-demand
 - + Mixes and single species collections
 - + Some high quality, UK-origin material is available
 - + No requirement for – or collecting
- Limited range of local-origin material
 - Limited range of species
 - Quality is variable



Green Hay

- + Transfer large quantities of seed
 - + Cheap, simple technique using conventional machinery
 - + **Hay mulch can promote germination and establishment**
- Captures a single 'snapshot' of species
 - Donor and recipient sites must be close together





Brush Harvesting

- + Harvest large quantities of seed
 - + Multiple harvests capture a broad range of framework species
 - + Limited damage to sward
 - + Seed can be stored until needed
- Some species missed – growth characteristics, phenology etc.
 - Requires careful post-harvest drying, cleaning and storage of seed

Hand Harvesting

- + Species specific
- + Collect from species and sites inaccessible to machinery
- + Supplement species missing from brush harvests
- Labour intensive
- Requires good plant/seed ID skills and the ability to assess ripening and dispersal
- Must be carried out responsibly to avoid depleting wild populations





Plug Planting

- + Overcome complex germination requirements
 - + Introduce plants to competitive, established habitats
 - + Efficient use of small seed collections
 - + Public engagement opportunities
- Expensive and time consuming
 - Vulnerable to drought and uprooting

Comparative Costs

	Commercial Seed	Brush & Hand Harvested Seed	Plug Plants	Natural Regeneration
Site preparation (£/ha)	200	200	100	200
Seed/plants (£/ha)	2200	4500	25000	0
Planting/sowing (£/ha)	100	100	500	0
Total costs	£2500	£4800	£25600	£200
Costs ratio	12.5	24	128	1
Loss of grazing value (£20/ha)	20	20	0	40
Loss of subsidy (£200/ha)	200	200	0	400
Total losses	£220	£220	£0	£440
Losses ratio	0.5	0.5	-	1
Total costs + losses	£2720	£5020	£25,600	£640
Costs + losses ratio	4.3	7.8	40	1

Estimated costs associated with seed sourcing strategies in UK calcareous grassland managed by grazing.

Summary:

- Seed have ability to persist (in situ and ex situ), supporting natural regeneration of landscapes;
- Aim: enhanced restoration with well-adapted, appropriate species needs:

Science

- More trained staff;
- Better information on seed quality through research (germination, dormancy, processing, etc.).
- Greater compilation and sharing of knowledge.

Policy / regulation changes needed

- Involvement of government regulation on quality assurance for native species (not DUS).
- Evolution of national agricultural systems to develop the agronomy of native species (beyond crops).
- Improved availability of seeds from industry, achieved by developing the native species seed supply chain (without overharvesting from the wild).