Maximising the use of native seeds in restoration projects

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EDITORIAL

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In many nature conservation or mitigation projects the re-establishment of native plant species is hindered by the lack of availability of a suitable soil seed bank or nearby source area for re-colonisation. The increasing number of restoration projects around the world has created a demand for seed material of native species. The Bonn Challenge to bring 350 m ha of the world's deforested and degraded land into restoration by 2030 (http://www.bonnchallenge.org/content/challenge), could require more than one million tonnes of seed at a sowing density 4 kg ha^{-1}. Wild harvest of this quantity of material is unsustainable. Consequently, the need to multiply native seed through cultivation from wild-collected seed on specialised farms is increasingly important. However, the adaptation of native seed for these purposes is hindered by uneven germination of seed lots, a dependence of seed viability on the conditions of parent plants, which can vary from year to year, and the uncertainty about the factors that determine the success rate of establishment in a particular restoration site. A second consideration is that the seeds that are being cultivated from wild material are unintentionally submitted to selection and lose their adaptations to specific natural habitats or may become genetically less diverse.

A deep understanding of the biology and ecology of seeds, the potential pre-treatments to enhance germination and the factors that are key in establishing and persisting in a community is essential for the successful use of native seed. To increase the collaboration between scientists in plant ecology, genetics, molecular biology, taxonomy, ecology, conservation, seed biology, environmental science, agricultural botany, crop science, breeding and horticulture, an international training network was formed with the specific purpose of improving understanding of seed biology, solving industry-related challenges and increasing public awareness of the role of seeds in restoration projects. This training network, with the acronym NASSTEC (NAtive Seed Science, TEchnology and Conservation), organised an international symposium at the Royal Botanic Gardens, Kew, in September 2017, at which most of the papers published in this special issue were presented.

The papers in this Special Issue are broadly clustered around the following topics: technical advances, seed quality for restoration, methods to improve seed germination in dormant seed lots, demands imposed by changing environmental conditions, and the role of national policies in the use of native seed.

TECHNICAL ADVANCES

Methods to grade, qualify and assure suitability of seed prior to application depend on the development of non-destructive techniques that aim to measure traits that can be used to assess the suitability of seed for use in restoration projects. Di Cecco *et al.* (2019) used image analysis techniques to quantify morpho-colorimetric variables and describe shape, size and colour; and used Fourier-transform infrared (FTIR) spectroscopy for the chemical characterisation of the seeds. Similarly, seeds of *Lathyrus linifolius* were characterised using physical, colorimetric and chemical techniques (Dello Jacovo *et al.* 2019). In contrast, Blandino *et al.* (2019) used micro-CT scanning as an innovation to assess the micro-anatomy of seed and embryo growth through the germination process, supported by traditional dissection and advanced image analysis techniques.

SEED QUALITY

To meet the high demand for seed in restoration projects, specialised farms produce seeds from plant material collected in the wild. The growth conditions on these farms impose environmental conditions on the plants that could differ strongly from those experienced in nature. Plants thus might be subjected to unintended selection pressures and lose traits that are best suited to their natural habitat. This selection counteracts the care that is normally taken during cultivation to maintain the genetic variation as far as possible. Using AFLP markers and phenotypic characterisation, Nagel *et al.* (2019) found that large-scale propagation can indeed, in some species, cause evolutionary changes.

The study of the hemi-parasite *Rhinanthus minor* (Marin *et al.* 2019a) focused on the effect of seed quality (specifically germination and vitality of the germinating seedling) on the ecological effect of introduction of this species for restoration purposes. Factors that potentially negatively affect species' seed quality are, for instance, long-term dry storage (Magrini *et al.* 2019) and underground storage (Amartuvshin *et al.*, 2019). Although maternal effects on seed dormancy and germination, mediated by the light receptor phytochrome, have been described for the model plant *Arabidopsis*, this aspect of seed biology has not been given sufficient attention in native wild plant species. In *Primula vulgaris* effects of light conditions mimicking a closed or open canopy on leaf thickness, area and chlorophyll content were observed, but effects on germination were absent. Germination was high under 'open gap' conditions and low when shaded by a leaf cover, regardless of the light conditions experienced by the mother plant (Marin *et al.* 2019b).

CHANGING ENVIRONMENTAL EFFECTS

With the increasing occurrence and intensity of extreme weather events, including drought and related wild fires, hurricanes and flooding, native seed is increasingly required in large quantities to build ecological resilience (outlined by Oldfield 2019).

Several studies focused on the effects that changes in climate parameters (temperature, moisture) or the consequences thereof (*e.g.* increased salinisation) have on seed quality and germination.

In three milkweed (*Asclepias*) species, the germination response to stratification followed by incubations at higher temperatures were recorded. The latitude of origin of the species was found to have significant effects on the breadth of the temperature range for germination. A result that suggests an interaction between source climate and life history (Finch *et al.* 2019). Based on an analysis of the intraspecific plasticity exhibited in morphology, colour and chemical composition of seeds of four populations of *Astragalus aquilanus*, Di Cecco *et al.* (2019) also concluded that climate variables strongly affect the type of seed produced. In contrast, a variation in environment associated with an altitudinal span of 1000 m had little effect on the germination of *Helichrysum microphyllum*, where all seed lots were non-dormant (Picciau *et al.* 2019). When changing rainfall patterns lead to prolonged periods of drought, it is more likely that plant communities will be affected by saline soil conditions. In the study of Foti *et al.* (2019) germination of six lentil genotypes was tested under three different salinity levels. All germination and early seedling growth traits measured were affected by salinity, although the genotypes showed variation in the severity of the salt effect.

In a comparative study, the dispersal and morphometric characteristics of the endangered yam *Dioscorea strydomiana* were compared with other species in the genus. Mattana *et al.* (2019) found that in most traits, *D. strydomiana* had lower phenotypic plasticity than the other examined species. Germination in *D. strydomiana* was lowest and was more strongly inhibited at higher temperature than its sister species, a combination of traits that suggest strongly reduced reproductive success.

IMPROVING SEED GERMINATION

Efforts to re-establish native plant communities from seed commonly fail, sometimes because the seed dormancy type is not characterised and appropriate environmental conditions to enhance germination are unknown. Kildisheva *et al.* (2019) classified the seed dormancy of 26 key species of the dryland ecosystem of the Great Basin in the USA using a wide temperature range and applying gibberellic acid and karrikinolide, well known dormancy-breaking compounds. Various dormancy types (physiological, physical, a combination of the two and morphophysiological) were observed and, in all but one species, germination was inhibited below 10 °C. Adding a layer of environmental complexity, Frischie *et al.* (2019) found for 13 ruderal dicots from southern Spain that germination efficiency was affected by a combination of water availability and temperature rather than physiological dormancy. Finally, across a wide spectrum of 23 key herbaceous species for use in European habitat restoration, Lopez del Egido *et al.* (2019) found that species that share a similar environment have similar light requirements for germination, while differences exist among species in their responsiveness to other germination cues. Consequently, enhancing germination may demand a species-by-species approach. In this issue, two studies explored the technical options currently available to improve germination performance. In one study, on the micro-seeds of orchids, treatment with laccase to increase the rate of seed coat degradation proved promising (Pierce *et al.* 2019), while in a second paper, on Australian native grasses, treatment with sulphuric acid, followed by manual cleaning improved germination (Pedrini *et al.* 2019).

NATIONAL POLICIES

The final three papers present the role of national authorities in restoration projects in Brazil, the USA and Germany. In Brazil the scarcity of seed material for large-scale projects is a severe bottleneck. Based on experiences with three successful community-based projects, the authors identify four requirements: (i) matching seed production to real demand; (ii) governmental and non-governmental organisation support for local initiatives, particularly in legal, organisational and marketing issues; (iii) making use of local knowledge on species ecology and using the local labour force; and (iv) solving technical issues and developing novel techniques based on (applied) science (Schmidt *et al.* 2019).

Some of these issues have already been addressed within the US National Seed Strategy for Rehabilitation and Restoration. Twelve federal agencies and over 300 non-federal groups collaborate to ensure that genetically appropriate native seeds are available for ecological restoration. To enable this, the consortium tries to identify the need for specific seed type, the availability of genetically suitable seed, and support research projects to improve the quantity and quality of seed produced as well as evaluate the success of restoration projects (Oldfield 2019).

Although restoration projects depend on the use of seeds from native, regional wild plants, in Germany such seeds only make up 1% of the total seeds used for greening projects (Mainz and Wieden, 2019). A European quality assurance system has been developed, but this does not cover the whole chain from seed production to restoration project, as it ends with the sale of the seeds. The consequence is that unmonitored seed lots, often unsuitable and foreign to the region, are being used. The authors in this Special Issue recommend establishment of broadly agreed recommendations for the EU member states, spearheaded by nature conservation, to define standards for producing and using native seed. With this in mind, one additional positive outcome of the NASSTEC project has been the formation of a European Native Seed Producers Association.

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