Scottish Wildflower Seeds: Production and Use

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Summary

In this brief review, the use of wild flower seeds is described as a contribution to the enhancement of biodiversity and as a way of improving grassland and other plant communities. Ecological concerns about sowing seeds in locations that are climatically contrasted to the countries from which the seed is sourced are discussed. Characteristics that aid the spread and survival of normally uncultivated species create difficulties in seed production and use. Establishment of a crop for seed production and subsequent weed control can be troublesome and procedures to achieve these have been developed based on experience. Harvesting methods are selected and modified to suit the maturity and dispersal characteristics of different species. Drying and processing, to ensure the removal of a large proportion of the unwanted material, such as appendages that aid wind dispersal, insect parts and weed seeds, can consist of as many as 10 stages for some species. As the final stage in production, seed quality control of wild flower seeds through germination testing has not been routine in the past. Our research has identified appropriate dormancy breaking treatments for a range of species, so that we currently can test the quality of seeds both from different harvest years and periods of storage.

Key words: wildflower seeds, production, treatment, use.

Introduction

In the public mind the name Rothschild is associated with banking. In science, Dr Miriam Rothschild FRS, a member of the banking family who died in 2004 aged 96, was a world renowned entomologist. She was also a pioneer in establishing wild flower meadows on her estate in Sussex several decades ago. As might be expected of an entomologist, one of Dr Rothschild's objectives was to increase the numbers and diversity of butterflies and other insects. In a contrasting urban context, wildflowers have been sown over the past 20 years to create striking visual effects in parts of Liverpool as part of an urban regeneration scheme. The use of seeds of native plant species now ranges from comprehensive plant community restoration over large areas to growing a few plants in tower block window boxes.

There are five major producers of wild flower seed in the UK, including one in Scotland, Scotia Seeds based near Brechin. The increase in production has followed the interest in using wildflower and grass mixtures of an increasing number of species in places beyond gardens and estates. At the same time, the problems of seed production, storage and use should not be underestimated. Many of these have been overcome by experience, but equally many more remain and the application of a scientific approach is required to resolve some of the difficulties which have not been overcome by practice and observation. Some of these problems are the subject of investigation at Scotia Seeds in association with seed scientists from Aberdeen University.

The widespread use of wild flower seeds raises some interesting technical and ecological concerns for botanists and in this brief review we hope to summarise the way in which wild flower seeds are being used and to outline the issues. Some of the methods used in production at Scotia Seeds since the company was set up in 1995 will be described. Our recent work, supported by a Scottish Executive Smart Award, is also included. This focuses on developing methods to break seed dormancy to enable routine testing of seed quality, as well as a new initiative to treat bulks of seed before sowing to improve reliability of performance in the field.

Using Wildflower Seeds to Enhance Biodiversity

Miriam Rothchild's early initiative to increase biodiversity with wild flower meadows, described above, was developed further by Wells *et al*. (1981) and others as they sought reliable methods to create diverse grassland communities. This work pre-dated the global interest in biodiversity, marked by the UN Convention on Biological Diversity agreed in Rio in 1992. From this followed the UK Action Plan on Biodiversity (Anon, 1994) and a review of the needs of Scotland (Mitchell *et al*., 2000). Among the key areas identified was the need to re-establish plant populations in the wild. Although seed production at Scotia Seeds does not generally include endangered species, many of the species we deal with have disappeared from large areas of the country, and experience with these plants can be used to enhance populations of rare or threatened species, before they become endangered.

The Botanical Society of Scotland has already contributed to the biodiversity debate with their 2002 Symposium on Plant Conservation in Scotland. A point made in that Symposium was that, because of climate, Scotland, with just over 1000 species, is not rich in vascular plants (Gibby, 2003). Thus any further loss of species would be especially regrettable. In the Symposium conclusions, Crofts (2003) made recommendations including two that are relevant to our present review. He highlighted the need for new scientific knowledge to improve the success of habitat restoration and plant re-introduction, and argued for a communication strategy for plant conservation to gain community support. We suggest that floral displays of Scotland's plant diversity in unexpected places, such as roadside verges and former industrial sites, not only improves the visible environment but will also bring to the attention of a wider public the benefits and needs for conservation. For example, the rare Greater Yellow Rattle (*Rhinanthus angustifolius* Gmelin) was recently sown in a wildflower seed mixture on a new roundabout south of Arbroath, close to one of its few remaining sites in the wild.

Between the 1940s and 1980s there has been a loss of habitats where wild flowers flourish, largely associated with the intensification of agriculture. In England, for example, Fuller (1987) estimated that species-rich grassland declined by 97% during that period. The situation is similar in Scotland and the recognition of this loss has led to initiatives such as the inclusion of grants and subsidies for creation of 'species rich grassland' in the Rural Stewardship Scheme and the preceding agri-environment scheme, the Countryside Premium Scheme. These schemes are supported by advisors from the Farming and Wildlife Advisory Group, Scottish Agricultural College, Scottish Natural Heritage and independent advisors. The formation of the Scottish Wildflower Grassland Forum in 2000 brought many of these groups together to allow discussion of the technical and administrative effort to create and manage species rich grassland. Meadows have been the main focus but the ground flora of woodlands has also been included, particularly as many newly-planted woodlands of native tree species have been established. These are now reaching the point where the canopy is providing shade at ground level giving conditions suitable for the establishment of woodland floor species. In most cases, as with meadow creation, there is no seed bank for these species to appear naturally and migration is extremely slow, so seed introduction has been investigated (Francis *et al*., 1992). Wetland areas have also been restored using wildflower seeds, for example the creation of new areas designed specifically for newts to allow the redevelopment of the former Ravenscraig steelworks site. Moorland restoration is also likely to become increasingly important as pressure grows on upland areas for leisure and for developments such as wind-farm construction.

A survey of the views of residents and visitors to Loch Lomond and Stewartry Environmentally Sensitive Areas revealed a consistent view that wild flowers are one of the most valued landscape features (Gourlay & Slee, 1998). Current concerns about food quality, animal welfare and environment have led to an examination of the effects of a wide diet of plants on the quality milk (Cabiddu *et al*., 2005). Other interest in the use of native plants has come from the potential for using plant extracts for industrial, food or cosmetic products, with a consequent requirement for a supply of seed of species not normally associated with plant community restoration. An example of this is the use of bog myrtle, *Myrica gale* L., for the cosmetics industry.

An appraisal of the effectiveness of ecological restoration (Pywell *et al*., 2002) not only highlighted the difficulties of restoration ecology but also revealed the scale of interest, with the inclusion of 25 case studies of species rich grassland restoration on intensively managed agricultural lowland in Britain. Warren *et al*. (2002) summarised the results of trials in Scotland of management treatments in the establishment of semi-natural grassland communities. Links between restoration ecology and conservation biology have also been made in work that has included derelict former industrial land (Bradshaw, 1987; Dobson *et al*., 1997).

Ecological Issues

A great deal of regulatory legislation, both in the EU and UK, covers the trading of seeds of plants used in agriculture, but none exists specifically for seeds of wild plants, except for the prohibition of trade in material of species included in Schedule 8 of the Wildlife and Countryside Act (1981). The Fodder Seeds Regulations (1993) of the Plant Varieties and Seeds Act (1964) coincidentally cover some native species which are used in agriculture in the European Union including grasses (*e.g. Festuca rubra* L.) and forage legumes (*e.g. Lotus* *corniculatus* L.). These regulations require all seed sold of these species to be certified, *i.e.* to be of a named cultivar and to meet minimum standards of germination and purity. As wild populations cannot meet the requirements for registering a cultivar (a test for distinctness, uniformity and stability) the seed sold as wild material of these grasses and forage legumes has been in breach of this legislation. Recently attempts have been made in England to incorporate seed of wild origin into the legislation but it is not yet clear how successful this will be. The situation in Scotland is likely to follow the English example.

A lively debate among the ecologically aware concerns the source of wild flower seed in relation to where it is used (Akeroyd, 1994) and how this should be regulated. Three types of material used as wildflower seed present a possible problem: non-native species which are considered to be wildflowers elsewhere; exotic populations of native species and agricultural or ornamental cultivars of native species. Interbreeding of introduced ecotypes and the native representatives of the species could lead to the erosion of native genetic variation with implications for fitness and survival. The example of Bluebell or Wild Hyacinth (*Hyacinthoides non-scripta* L.) which crosses with the introduced *Hyacinthoides hispanica* Miller to produce robust and persistent hybrids is well-known. Although *H. hispanica* has been introduced over a long period as a garden plant rather than a wildflower, it is easily confused by gardeners looking for bluebell bulbs or seed. The prohibition of sales of wild material of *H. non-scripta*, designed to prevent damage to native populations, actually makes it more likely that *H. hispanica* material will be used.

How far we should take this concern is also a matter of debate. Should we be using, in Scotland, only seeds from Scotland? Should we only use seed from populations within, say 50 km, of the site where it is to be sown? If the limitations are too tightly prescribed, the potential for production and use of wildflower seeds would disappear. However, there is pressure developing for some regulation. For example Flora Locale, a conservation charity formed to address the issues arising from the use of material of native species, has produced a Code of Practice, defining terms and setting out procedures (www.floralocale.org).

There is a need for evidence of the possible consequences of ecologically inappropriate introductions. Work in Switzerland on several wild flower species found differences in germination response to temperature between seed from, as they describe, provenances (origins) from different European countries (Keller & Kollman, 1999). Another ecologically significant difference between origins of the same species, imported into Switzerland, was the palatability to two species of slugs (Keller *et al*., 1999a). For all four species tested (*Cichorum intybus* L., *Daucus carota* L., *Leucantheum vulgare* L., *Silene alba* Miller) the Swiss slugs preferred plants produced by seeds from German and Hungarian origins to the English and Swiss plants. This example of different responses to herbivory would have consequences for the successful establishment of seed of origins from outside the area of sowing. It also illustrates that there are differences in populations which are not at first apparent. Further work by the same Swiss research group found more disturbing evidence of reduced fitness in Swiss plants of *Agrostemma githago* L. and *Papaver rhoeas* L. produced from crosses with English, German and Hungarian origins (Keller, *et al*., 1999b).

There does seem to be justification for reducing the use of wild flower seeds that are from sources which are climatically contrasted to the sowing site. The chances of failure to establish would be greater, and unrealised ecological consequences may result. At Scotia Seeds, all our sources of the original plant material are from Scotland. Thus we try to produce ecologically appropriate seed for use in Scotland, but have not gone so far as to limit sources within the country to close to the site of use because of the practical feasibility of such a policy.

The responses of wild plants to their physical environment, interactions with other species and the effect of management, create a large number of variables which can lead to a certain amount of unpredictability when seed of perhaps twenty or more species are sown together, into soil which already contains other seeds and where seeds can migrate in from around about. Sowings of meadow seed mixtures typically result in a succession of species, with annual weeds followed by species which grow most quickly in the conditions present. For example, in a mixture of seed formulated to create a neutral grassland type, *Leucanthemum vulgare* L. and *Achillea millefolium* L. frequently dominate in early years in conditions of high nutrient availability. If the same mixture is sown in nutrient-poor soil, *Vicia cracca* L., *Lotus corniculatus* L. and *Lathyrus pratensis* L. will cover a larger proportion of the ground initially. The concept of succession may be familiar to users of wildflower seeds in terms of the need for weed control in plant establishment, but the long-term changes of the balance of perennial species are less well known in landscaping, agriculture or gardening. The creation of semi-natural meadow communities is often an attempt to reproduce a balance of species which has arisen in ancient hay meadows only after decades or centuries of management by cutting and grazing. With a little knowledge and patience however, it is usually possible to achieve highly satisfactory results in a relatively short time.

In the use of wildflower seeds, the interactions and behaviour described above are often inconvenient. People establishing a wildflower meadow usually want to see an open sward with a wide range of species flowering over a long period and to achieve this result more quickly than the normal behaviour of the plants sometimes allows. Gardeners find seed dormancy inconvenient and farmers are used to establishing crops in one season. Landscapers often have the final task of a construction project, which must then be signed-off by the client before the contractors are paid. If wildflowers are only partly established, a judgement must be made about the success of the sowing before a relatively stable situation has been reached

Methods of Seed Production

In seed production the interactions described above and the characteristics associated with flowering, seed production and dispersal of individual species often make for interesting technical problems of cultivation and the management of seed production.

Early seed production of meadow species concentrated on harvesting directly from old meadows. This seems an obvious approach given that the desired species are present by definition and it is possible, with a little ingenuity, to find machinery to gather the material. In practice this approach presents a number of serious problems of yield and quality of seed, in that different species ripen at different times and produce varying amounts of seed. Some species may be under-represented or absent from the harvest and a meadow sown from the resulting seed may not represent the original balance. The optimum time for harvest may be very difficult to judge and much seed may be under-ripe, with low germination as a result. The product often contains a high proportion of stems and leaves as well as insects and other non-seed material and it is very difficult to clean this out. Donor sites can also be difficult to find and the logistics of harvesting in remote or inaccessible sites can make the operations very expensive. There is also concern about possible damage to precious ancient meadows.

By contrast, growing crops of individual species and harvesting them separately has a number of advantages, as it allows greater control over yield and quality and the species can then be mixed in a range of combinations for different uses. This is the practice at Scotia Seeds and is also the approach of most other seed producers. It also allows the study of individual species so that the cultivation of those which have difficult requirements can be improved. In practice, and for convenience, the problems of producing wildflower seed crops can be divided into those which appear in the growing crops and those which affect seeds and crop establishment.

Agricultural crop plants have been selected by the cultivation process over thousands of years and selection has changed them significantly from the original wild plants. The cultivation of wildflowers for seed represents an attempt to manage, in an agricultural way, about two hundred species which have never been grown as crops before, but without changing the characteristics of the populations. This requires a clear view of what we are trying to achieve and a highly organised approach to managing the populations of plants that are being handled. In addition to the question of seed origin in relation to its site of use discussed earlier, there is little or no data about the effect of cultivation to produce seed crops on the variation within or between populations. While a precautionary principle is often applied, where production is limited to a few generations of seed multiplication from the original collection, it would be worthwhile investigating this aspect of the use of wildflower seeds.

Ploughing and preparing the ground for cultivation offers an opportunity for annual weeds to appear and their control or management is a major issue in crop production. Strategies include tolerance of high density weed infestations in the initial establishment year and subsequent recovery of perennial species. Also weeds which do not appear to damage yield significantly can be accepted, provided that any seed can be cleaned out of the harvested crop. These judgements vary from species to species and practical experience is the key to successful harvesting. Perennial weeds can be dealt with by spot application of herbicide or mechanically by inter-row cultivation or hoeing. A significant advantage of single-species crops is that many species will survive in an arable situation which may differ markedly from their normal habitat – the removal of competition often allows wetland plants to grow in crops side-by-side with dryland species. Yields can be improved by application of fertiliser and an increase in plant spacing can reduce interplant competition.

Approaches to harvesting wildflower seed are largely based on experience and an understanding of the behaviour of the plants. Wheat, barley and other cereals have been selected to ripen evenly and retain the ripe seed on the plant. The uniform result is easily mechanised and the time of harvest relatively straightforward. Many wild plants have seed which matures over a long period of time and is dispersed quickly so that there is only a small proportion of ripe seed on the plants at any given moment. To obtain the maximum yield, producers must judge the moment of maximum ripe seed, harvest sequentially and, in general, adapt the approach to suit the species. Some equipment and techniques from plant breeding operations and vegetable and ornamental flower seed production can be used or refined but this area remains difficult. Small scale combine harvesters offer the easiest harvesting and perform well with crops which ripen relatively uniformly (*e.g. Leucanthemum vulgare* L.). They can be used after swathing (cutting and drying in rows), sometimes going over the crop several times (*Vicia cracca* L.). Brush harvesters offer an alternative with unevenly-ripening crops. Specialised forage harvesters will pick up crops where the seed quality is improved by post-harvest maturing or damaged by threshing (*Primula veris* L.) and separation of seed from other plant material after drying. Vacuum harvesting can be used for some species where seed is dispersed by wind, dandelion-style (*Leontodon autumnalis* L.). Hand harvesting can be essential where seed matures below foliage or very close to the ground (*Primula vulgaris* Hudson) and the seed heads are either picked or cut. Where seeds are dispersed explosively, they can be collected from the ground or from sheets after shedding (*Cardamine pratense* L.).

Wildflower seeds are often harvested at high moisture content and the harvest frequently contains large amounts of green stem and leaves. Once harvested, the seed has to be dried and there is always the danger of loss of viability if drying temperatures rise too much in damp seeds. Seed can be spread out on sheets in polytunnels or dried by blowing air though the material. The seed appendages that aid dispersal, by for example the wind, do not always readily fall away from the seeds of wild plants. To clean the seed to a dispersal unit without a large proportion of inert material is a time-consuming, but necessary, stage. Buyers of wild flower seeds do not expect to buy too much material that is not the living seed. In some seeds, as many as ten processing stages are involved from drying, threshing, rubbing and combinations of operations to sieve and winnow to separate seed from stems, leaves, weed seeds, insect parts, stones and soil. Further separations can be made on the basis of specific gravity, rolling properties (shape and presence of hairs) and other characteristics. These operations result in pure seed and also enhance the germination of seed lots by removal of immature and damaged seeds.

Quality Control and Improvement

Seed dormancy in wild plants ensures that plant establishment is spread over time and is triggered by stimuli that improve the chance of seedling survival. The need for a low temperature period to break dormancy increases the chance of a spring germination after winter. For some species the need for light triggers germination when seeds are at the surface of the soil; in other species dark conditions are

Table 1. Summary of stimuli used to break dormancy in wild flower seeds.

Method	**Description**
Prechilling	Moistened seed held at 5°C for up to 6 weeks
Scarification	Testa of dry seeds scored with sand paper
GA_3	A solution of the growth hormone Gibberellic acid is added to the germination medium
KNO_3	A solution of potassium nitrate is added to the germination medium
Alternating temperature	Different temperatures are used for the day/night period during the germination test
Washing	Seeds are washed in running water for several hours

needed. The complex mechanism of light stimulation is also thought to favour germination away from the shade of competing plants.

A recent focus at Scotia Seeds has been on testing seed to ensure that buyers receive wild flower seed with a high, or at least predictable, proportion of viable seeds with a good chance of establishing plants in the field. The innate dormancy of many species makes laboratory testing more time consuming and complex than the procedures used for crop seeds, for which there are proven and standardised methods, backed up by legally framed regulations (Anon, 2006).

Over the last three years, we have tested 120 species from our seed stocks harvested over a number of years. Around 44 species showed dormancy, that is, without a dormancy breaking stimulus (Table 1), less 50% of the seed would germinate in moist warm conditions. The method required to break dormancy differs between species but often methods are plant family group specific. Some examples are shown in Table 2. Guidelines on the appropriate method may often, but not always, be found in the scientific literature. Much of the methodology remains in-house knowledge. We are currently working towards establishing routine methods for different species, with a view to working with official seed testing laboratories in several countries to validate the methods with the International Seed Testing Association (ISTA). The development of test methods will not only give greater assurance to buyers about the quality of the seed, but also enable us, as seed producers, to evaluate more scientifically the methods of production and seed storage that we are using.

The seed that users buy not only has to germinate in the laboratory, but also produce plants in the field. Natural dormancy leads to a spread of emergence over time, and this can lead to disappointment for the user of the wild flower seed mixture. Poor establishment can also allow colonisation of undesirable species in the gaps. Another initiative that we are following is a priming treatment of bulks of seed to break dormancy so that, when included in the mixture, a proportion of the sown species will germinate and establish more quickly. This has proven useful in the production of wild flower plants in the field and in plastic tunnels, a method used by some plant producers for the sale of plug plants. The modular production of *Primula veris* has been improved from 0% to 64% by the treat-

Table 2. Examples of seed responses to dormancy breaking treatment in laboratory germination tests.

Species	Family	Treatment method	Germination (%) Control	Germination (%) Treated
Succisa pratensis Moench	Dipsacaceae	Prechilling	0	43
Lotus uliginosus Schkuhr	Leguminosae	Scarification	48	96
Primula veris L.	Primulaceae	GA_3	14	79
Ranunculus acris L.	Ranunculaceae	KNO_3	12	40
Chenopodium album L.	Chenopodiaceae	Washing in running water	10	25

ment. Increasing reliability and visible success of wild flower mixtures will give encouragement to potential users and to the producers.

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