INDICES SEMINUM: ARE THEY REALLY WORTH THE EFFORT?

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This manuscript investigates whether *indices seminum* are currently aiding conservation or whether they require modernisation. It is widely assumed that the proportion of wild-collected seeds has increased within botanical seed lists. Through a number of studies we found the reverse to be true. Our paper also found that very widespread taxa were needlessly offered from garden origin. More worrying is that taxa well known for their invasiveness were also freely available for distribution. Another concern was the failure to supply or request associated data for wild-collected seeds despite its availability, a neglect counter-intuitive to botanic gardens. We highlight that in their present form *indices seminum* are a waste of resources and offer little to legitimate conservation. A range of recommendations is provided for modernising this activity in order to prioritise conservation, one of our biggest challenges of the 21st century.

INTRODUCTION

The distribution of seed material between gardens through *indices seminum* is believed to have started in the late 16th century when Jacob Bobart first compiled a list of seeds collected from the University of Oxford Botanic Garden. Other institutes embraced this practice and now in excess of 500 botanical seed lists are distributed annually. The activity of producing an *index seminum* remains a major endeavour in many botanic gardens and involves a significant investment in time and money, but is it an antiquated practice in need of modernisation and might the effort be better used?

Contemporary conservation theory asserts that the world's flora faces more unprecedented threats, as a result of climate change and other human-related activities, than ever recorded. According to predictions, these changes could be swift, with habitat and species loss incalculable. Urgent action is therefore required and botanic gardens have a significant contribution to make. Are botanic gardens rising to this challenge, or do they languish in the past, inadvertently diverting precious resources?

Aided by three investigations, this paper explores the value of *indices seminum* as a tool for conservation and research, and encourages the idea that resources would be better utilised for collecting for conservation, thus supporting botanic gardens' primary source of *ex situ* conservation, seed banking. This manuscript is particularly pertinent to those gardens that legitimately position 'conservation' in their mission statement.

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IN AN IDEAL WORLD

The perfect scenario would be the conservation of all plants in their natural environment. The role of botanic gardens could then concentrate on plant science and education. Unfortunately we are not, and probably never will be, in a position to leave plant protection solely to *in situ* conservation. Through the actions of humans, we are facing the largest extinction crisis in 65 million years (Raven 2004). Institutes must take up the challenge in supporting conservation in the field.

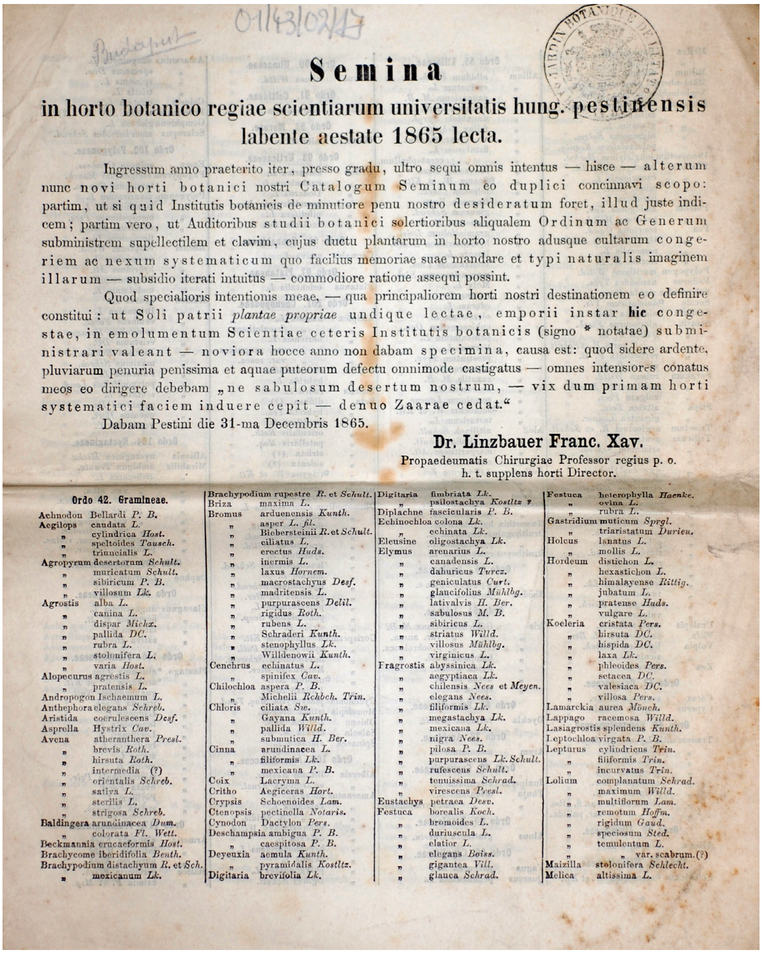
The primary goal of *ex situ* plant protection is to establish and maintain spores, seed and plants of wild species outside their natural habitat for the direct or indirect purposes of species reinforcement, reintroduction or relocation. This should preferably be in the country of origin as highlighted by Article 9 of the Convention of Biological Diversity (CBD) and Target 8 of the Global Strategy for Plant Conservation (GSPC). However, despite these recommendations, the disparity between the distribution of the world's flora and botanic gardens is great (Heywood, 1987). This implies that some endangered plants may require temporary protection far from their native range. This should only be considered as part of a legitimate recovery programme.

COLLECTING FOR CONSERVATION

Across the world, thousands of botanic garden staff are involved in seed collecting both from the wild and from plants growing in botanic gardens. The majority of this effort is focused on obtaining material for the annual *index seminum.* Is collecting for this endeavour as important as it once was, or have times changed so much that these practices need new focus? The authors of this manuscript believe the latter and that emphasis should now focus on 'collecting for conservation'. This action need not be confined to threatened species. Many species currently considered 'safe' will decline markedly in their distributions if predictions of climate change and habitat loss are to be believed (The Grand Canaria Declaration II 2006, Intergovernmental Panel on Climate Change 2007). Now is the time to capture their genetic diversity, not when it has all but disappeared. In order for this to happen, a re-evaluation is necessary of our motives for collecting seeds and whether the returns on this investment are worth the effort. Are *indices seminum* currently contributing significant benefits to botanical pursuits, or do they represent a bygone era fulfilling practices that would be more effectively executed by other methods, such as targeted requests for species via the Botanic Garden Conservation International's (BGCI) *Plant Search* database, or more directly from online living collections' catalogues?

LIMITATIONS OF GARDEN-GATHERED SEEDS

As indicated above, the accessions offered in botanical seed lists normally comprise two very different types of material: that collected from plants growing in *ex situ*



Semina

in horto botanico regiae scientiarum universitatis hung. pestinensis labente aestate 1865 lecta.

Ingressum anno praeterito iter, presso gradu, ultro sequi omnis intentus — hisce — alterum nunc novi horti botanici nostri Catalogum Seminum eo duplici concinnavi scopo: partim, ut si quid Institutis botanicis de minutiore penu nostro desideratum foret, illud juste indicem; partim vero, ut Auditoribus studii botanici solertioribus aliqualem Ordinum ac Generum subministrem supellectilem et clavim, cujus ductu plantarum in horto nostro adusque cultarum congeriem ac nexum systematicum quo facilius memoriae suae mandare et typi naturalis imaginem illarum — subsidio iterati intuitus — commodiore ratione assequi possint.

Quod specialioris intentionis meae, — qua principaliorem horti nostri destinationem eo definire constitui: ut Soli patrii *plantae propriae* undique lectae, emporii instar **hic** congestae, in emolumentum Scientiae ceteris Institutis botanicis (signo * notatae) subministrari valeant — noviora hocce anno non dabam specimina, causa est: quod sidere ardente, pluviarum penuria penissima et aquae puteorum defectu omnimode castigatus — omnes intensiores conatus meos eo dirigere debebam „ne sabulosum desertum nostrum, — vix dum primam horti systematici faciem induere cepit — denuo Zaarae cedat.“

Dabam Pestini die 31-ma Decembris 1865.

Dr. Linzbauer Franc. Xav.
Propaedeumatis Chirurgiae Professor regius p. o.
h. t. supplens horti Director.

Ordo 42. Gramineae.

Achnodon Bellardi *P. B.*
Aegilops caudata *L.*
„ cylindrica *Host.*
„ speltoides *Tausch.*
„ triuncialis *L.*
Agropyrum desertorum *Schult.*
„ muricatum *Schult.*
„ sibiricum *P. B.*
„ villosum *Lk.*
Agrostis alba *L.*
„ canina *L.*
„ dispar *Michx.*
„ pallida *DC.*
„ rubra *L.*
„ stolonifera *L.*
„ varia *Host.*
Alopecurus agrestis *L.*
„ pratensis *L.*
Andropogon Ischaemum *L.*
Anthephora elegans *Schreb.*
Aristida coerulescens *Desf.*
Asprella Hystrix *Cav.*
Avena atheranthera *Presl.*
„ brevis *Roth.*
„ hirsuta *Roth.*
„ intermedia (?)
„ orientalis *Schreb.*
„ sativa *L.*
„ sterilis *L.*
„ strigosa *Schreb.*
Baldingera arundinacea *Dum.*
„ colorata *Fl. Wett.*
Beckmannia erucaeformis *Host.*
Brachycome iberidifolia *Benth.*
Brachypodium distachyum *R. et Sch.*
„ mexicanum *Lk.*
Brachypodium rupestre *R. et Schult.*
Briza maxima *L.*
Bromus arduenensis *Kunth.*
„ asper *L. fil.*
„ Biebersteinii *R. et Schult.*
„ ciliatus *L.*
„ erectus *Huds.*
„ inermis *L.*
„ laxus *Hornem.*
„ macrostachyus *Desf.*
„ madritensis *L.*
„ purpurascens *Delil.*
„ rigidus *Roth.*
„ rubens *L.*
„ Schraderi *Kunth.*
„ stenophyllus *Lk.*
„ Willdenowii *Kunth.*
Cenchrus echinatus *L.*
„ spinifex *Cav.*
Chilochloa aspera *P. B.*
„ Michelii *Rchbch. Trin.*
Chloris ciliata *Sw.*
„ Gayana *Kunth.*
„ pallida *Willd.*
„ submutica *H. Ber.*
Cinna arundinacea *L.*
„ filiformis *Lk.*
„ mexicana *P. B.*
Coix Lacryma *L.*
Critho Aegiceras *Hort.*
Crypsis Schoenoides *Lam.*
Ctenopsis pectinella *Notaris.*
Cynodon Dactylon *Pers.*
Deschampsia ambigua *P. B.*
„ caespitosa *P. B.*
Deyeuxia aemula *Kunth.*
„ pyramidalis *Kostltz.*
Digitaria brevifolia *Lk.*
Digitaria fimbriata *Lk.*
„ psilostachya *Kostltz ?*
Diplachne fascicularis *P. B.*
Echinochloa colona *Lk.*
„ echinata *Lk.*
Eleusine oligostachya *Lk.*
Elymus arenarius *L.*
„ canadensis *L.*
„ dahuricus *Turcz.*
„ geniculatus *Curt.*
„ glaucifolius *Mühlbg.*
„ lativalvis *H. Ber.*
„ sabulosus *M. B.*
„ sibiricus *L.*
„ striatus *Willd.*
„ villosus *Mühlbg.*
„ virginicus *L.*
Fragrostis abyssinica *Lk.*
„ aegyptiaca *Lk.*
„ chilensis *Nees* et *Meyen.*
„ elegans *Nees.*
„ filiformis *Lk.*
„ megastachya *Lk.*
„ mexicana *Lk.*
„ nigra *Nees.*
„ pilosa *P. B.*
„ purpurascens *Lk. Schult.*
„ rufescens *Schult.*
„ tenuissima *Schrad.*
„ virescens *Presl.*
Eustachys petraea *Desv.*
Festuca borealis *Koch.*
„ bromoides *L.*
„ duriuscula *L.*
„ elatior *L.*
„ elegans *Boiss.*
„ gigantea *Vill.*
„ glauca *Schrad.*
Festuca heterophylla *Haenke.*
„ ovina *L.*
„ rubra *L.*
Gastridium muticum *Sprgl.*
„ triaristatum *Durieu.*
Holcus lanatus *L.*
„ mollis *L.*
Hordeum distichon *L.*
„ hexastichon *L.*
„ himalayense *Rittig.*
„ jubatum *L.*
„ pratense *Huds.*
„ vulgare *L.*
Koeleria cristata *Pers.*
„ hirsuta *DC.*
„ hispida *DC.*
„ laxa *Lk.*
„ phleoides *Pers.*
„ setacea *DC.*
„ valesiaca *DC.*
„ villosa *Pers.*
Lamarckia aurea *Mönch.*
Lappago racemosa *Willd.*
Lasiagrostis splendens *Kunth.*
Leptochloa virgata *P. B.*
Lepturus cylindricus *Trin.*
„ filiformis *Trin.*
„ incurvatus *Trin.*
Lolium complanatum *Schrad.*
„ maximum *Willd.*
„ multiflorum *Lam.*
„ remotum *Hoffm.*
„ rigidum *Gaud.*
„ speciosum *Sted.*
„ temulentum *L.*
„ „ var. scabrum.(?)
Maizilla stolonifera *Schlecht.*
Melica altissima *L.*

Fig. 1 *Indices Seminum* have been around since the late 16th century, but are they fulfilling the needs of a modern botanic garden? This example dates back to 1865 and contains no more accession information as some of those produced today. Photo: David Aplin

collections and those harvested from wild populations. The usefulness of these differently sourced seeds varies considerably. Seeds collected from the wild can be utilised in conservation and research while garden-gathered seeds are best suited to education and display. There are several good reasons for this. Firstly, the genetic variability of seeds collected from cultivated individuals will almost certainly represent a fraction of the potential found in natural populations (Maunder *et al.*, 1999), many taxa being represented by less than five individuals, and even those may sometimes be derived from the same individual plant. Secondly, the documentation will often be poor with a high frequency of collections having unknown provenance because of poor record keeping in the past.

Thirdly, cultivated plants are susceptible to hybridisation (Maunder *et al.* 2001). This is particularly true in botanic gardens since a wide-range of taxa is often grown in close proximity which may allow two closely related species that would naturally be geographically isolated to come into contact and hybridise. Successful hybrids may demonstrate hybrid vigour and subsequently escape into nature where they can become invasive (Vilà *et al.*, 2000; Ellstrand & Schierenbeck, 2000) and threaten native flora (Rieseberg & Gerber, 1995; Stace, 1975).

Fourthly, cultivated plants encounter vastly different selection pressures than those from wild populations. This is partly for eco-geographic reasons and partly because horticultural tradition tends to favour the selection of vigorous plants; poor performers under garden conditions may be weeded out despite the fact that they may have genetic characteristics that bestow fitness in their native habitat. Selection is particularly true if the plants are short-lived outbreeders and maintained repeatedly from garden collected seed. Genetic drift, the random loss of unusual alleles, may occur. Furthermore, inbreeding depression and reduced fitness is likely. This has been studied extensively in *Lupinus texensis* (Helenurm & Schaal, 1996) and is the possible reason for a marked decline in fruit set and seed development in *ex situ* collections of the Amazonian water lily, *Victoria amazonica* (Stephen Forbes, Adelaide Botanic Garden, *pers. comm.*). Plants of this species grown at the National Botanic Garden of Belgium (NBGB) once produced over 10 fruits per year, each containing over 200 seeds, however since 2001 only c.50 seeds are annually available for harvest (J. Van den Eede, NBGB, *pers. comm.*).

Finally, while seed lists offer a wide variety of taxa, they are heavily biased towards annual and herbaceous taxa from families such as Asteraceae, Boraginaceae, Caryophyllaceae and Scrophulariaceae (Maunder *et al.* 2001). This is because these taxa often provide the possibility of collecting sufficient quantities of seed, not always an easy task for botanic gardens with few representatives of individual species.

These factors generally restrict the usefulness of garden-gathered seed for conservation and many research projects. Therefore, it is interesting to determine to what extent these seeds are offered in *indices seminum* and then to look in detail at some of the taxa that are currently available for exchange.

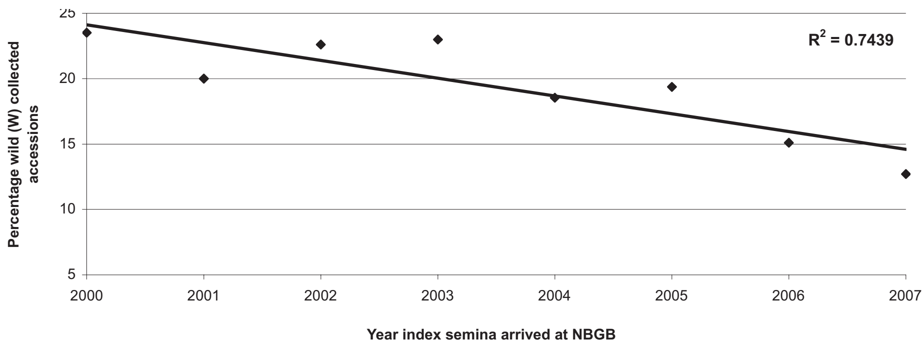
TURNING THE PAGES OF BOTANICAL SEED LISTS

Many consider that *indices seminum* play a significant role in contemporary conservation. They represent a greater proportion of wild collected material than they once did and contain plants that are of real value to botanic gardens. However these assumptions need to be supported by evidence. Consequently, the authors decided to delve through botanical seed lists to determine the percentage of wild collected seed material cited in European seed lists over the last eight years.

The NBGB annually receives around 500 *indices seminum* from around the world. Not surprisingly, the majority of these herald from Europe a continent with over a thousand gardens and arboreta (Rammeloo & Aplin, in press). The data within these lists reveal a range of useful information and highlight important trends.

In the first investigation, 200 randomly selected European *indices seminum* (25 for each of eight years) were assessed to determine whether the percentage of wild collected material had increased or decreased over the study period.

The values of wild and garden-gathered seeds for individual years were totalled (Appendix 1) and expressed as percentages (Graph 1). When this data was plotted a trend emerged demonstrating a reduction in wild-collected material in recent years. Wild-collected material fell from 23.5% in 2000 to 12.7% in 2007. This is surprising when the reverse trend is generally perceived to be true.

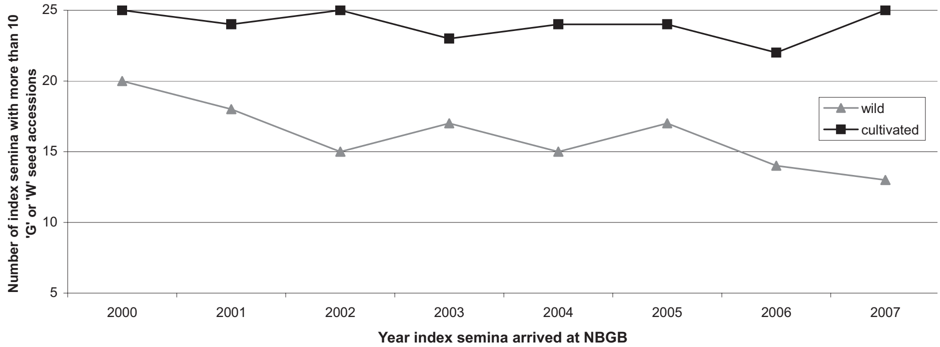


Graph 1 The percentage of wild-collected accessions listed in European seed lists between 2000 & 2007. Years refer to the arrival date of the seed list in the NBGB, not the collection date of material.

A possible cause for this trend may be due to a larger number of institutes simply not offering wild-collected material in their annual lists compared to a few years ago. In order to determine this, the number of lists offering wild-collected and garden-gathered accessions in each year were examined (Graph 2). *Indices seminum* containing less than 10 accessions of either criterion were discounted from this analysis because it was thought that their inclusion would skew the data.

The results in Graph 2 suggest that the number of seed lists comprising garden-gathered seeds remained fairly constant throughout the study period while the number containing wild-collected seed diminished. It might therefore appear that the cause for the decline in wild-sourced seed in recent years may be due to an increasing number of gardens electing not to offer them. Whether this has occurred as a result of increasing collection costs, increased difficulties associated with controlling benefit sharing resulting from implementation of the CBD or the material being utilised for other reasons is not known. However, this subject would warrant further study.

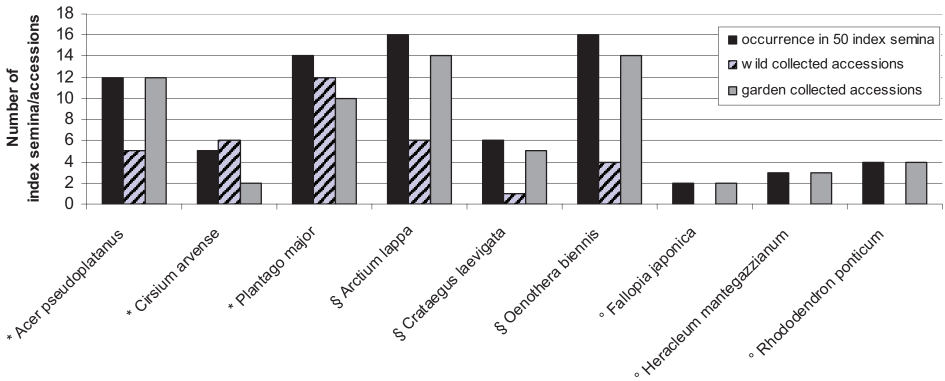
The combined number of accessions in the above 200 seed lists totalled 148,518, making an average list size of 743 (S.E.± 87) over the eight year period. From these,



Graph 2 The number of seed lists comprising of wild 'W' and garden 'G' collected accessions from the 25 seed lists assessed in each year between 2000 & 2007. Years refer to the arrival date of the seed list in the NBGB, not the collection date of material.

119,299 (80%) were gathered from *ex situ* collections, with the remainder from wild populations. Extrapolating to the 500 annual seed lists distributed to the NBGB (a conservative amount of the total globally produced), the number of accessions available to botanic gardens through *indices seminum* is around 372,000 per year of which about 300,000 will be garden gathered. This represents the expenditure of an enormous amount of effort by the botanic garden community. Making the not unreasonable assumption that each garden-gathered accession was collected every other year and took 30 minutes to collect, packet and document, this amounts to 75,000 hours of staff time per year or about 50 full time posts. Furthermore, this excludes the time to deal with seed requests. When postage costs are added, the total resource allocation is very significant especially at a time when many gardens have tight budgets. Even a reduction of this activity by half would free up resources to conservation; it would also help reduce the prevalence of a 'botanic gardens' flora' (same collections found in many gardens) thereby freeing up space and resources for carefully organised conservation, such as maximising the genetic representation of taxa.

The results from the first investigation are purely quantitative and explain nothing about the type of material offered. Consequently, a second study was conducted to look at a few selected taxa in greater detail. This study reviewed 50 randomly selected European seed lists arriving in 2007. The number of *indices seminum* listing each species were recorded along with the number of accessions collected from wild and garden origins (Graph 3). Nine species were selected that could be broadly classified into three groups: very commonly occurring European species, *Acer pseudoplatanus*, *Cirsium arvense* and *Plantago major*; species with high medicinal value, *Arctium lappa*, *Crataegus laevigata* and *Oenothera biennis*; species with well documented invasiveness in many areas of Europe, *Fallopia japonica, Heracleum mantegazzianum* and *Rhododendron ponticum.*



Graph 3 Occurrence of selected plant species in a random sample of 50 European seed lists. Data highlights the number of seed lists citing a particular species (black bars) and the quantity of wild (hatched bars) and garden (grey bars) accessions. '*' = commonly occurring in European species; '§' = plants with recognised medicinal properties; '°' = invasive species.

COMMONLY OCCURRING EUROPEAN SPECIES

The main purpose of *indices seminum* is to exchange, within the botanical community, interesting seed material. With this in mind it was surprising to observe very common species listed and a large percentage of their accessions derived from garden origin. *Plantago major* (Fig. 2), for example, described as *'one of the world's most widely distributed species'* (Sagar & Harper, 1964), was present in 14 (28%) of lists surveyed with twelve accessions from garden origin. *Acer pseudoplatanus,* a widely occurring tree species appears in 24% of lists with 70% of accessions sourced from garden-collected material. These two species have seeds that are easy to collect and it may be for that reason that they frequently populate seed lists rather than actual demand.

SPECIES WITH HIGH MEDICINAL VALUE

The selection criterion of this category was that it should represent European species with high medicinal value. In order to ascertain this, only species that scored the highest rating for 'medicinal use' on the '*Plants For A Future*' website (www.pfaf.org) were chosen. Biochemical research in particular may benefit from well documented wild collected accessions because plants from different provenance may produce varying concentrations of active ingredients (e.g. Sen-Sung *et al*. 2007). However, for each species, garden collected material predominated. Two species, *Arctium lappa* and *Oenothera biennis* were represented in 32% of *indices seminum*, but only 12 and 8 percent, respectively, were wild origin. *Crataegus laevigata* is however less widely distributed and this is reflected by its occurrence in only six lists and by its relatively high number of garden gathered accessions (Graph 3).

Fig. 2 Plantago major is one of the world's most ubiquitous species, is there really a need for them in seed lists? Photo: David Aplin.

INVASIVE SPECIES

A search was also conducted on a number of species with known invasiveness in Europe. Their occurrence in the lists was low. However, it was still a surprise to see them. Much has been written about the detrimental effects of *Fallopia japonica* (Fig. 3)*, Heracleum mantegazzianum* & *Rhododendron ponticum* on natural habitats as a result of their deliberate introduction by horticulture (Verloove, 2006; Maunder *et al.*, 2004; Milne & Abbott 2000; Stace, 1975). While threats by certain species to natural habitats depend on a range of complex factors, these species are particularly prone to invasiveness, especially in the counties offering their distribution. If there is demand for plant material of this kind for research into the causes of invasiveness then this would be better facilitated by direct requests rather than presenting them in a general list. Interestingly, out of 50 *indices seminum* studied only one mentioned any type of potential threat from invasive species while the majority also provided no indication about whether accessions had been verified. Some institutes have recognised the short sightedness of offering invasive, or potentially invasive, species and have terminated their seed lists (Jefferson *et al.* 2005).

It would appear that many of the nine species mentioned above may have been added to the *indices seminum* because they were easy to collect and readily available. Some collection managers are more circumspect and attribute 'actions' to their material based on a range of criteria (e.g. rarity, vulnerability, taxonomic value, horticultural merit) before adding taxa to their seed lists (see Vanderborght, 1997).

Fig. 3 Fallopia japonica is one of the most invasive weeds in many parts of Europe causing untold damage. Yet seeds of this species are cited in lists, despite male plants being sterile. Photo: David Aplin.

WORKING TOGETHER

An important development that could help avoid indiscriminate collection would be a centralised online seed list (perhaps hosted by the BGCI). Most *indices seminum* are now in electronic format so uploading their information to a centralised database would probably be straight forward. It would also allow for some analysis to be carried out on the information gathered and aid the collective future of this practice.

Botanic gardens should engage in networking their collecting activities with trusted amateur botanists (Alton & Linington, 2001). This action will greatly facilitate collection effort and with the aid of minimum collection standards (see later) and training not threaten the vulnerability of wild populations. Finally, botanic gardens must consider requests for wild-collected and endangered taxa with caution. There are often frivolous or indiscriminate requests, especially for rare and endangered species (FAO 1998) for seed material that in many cases would be better saved for conservation or scientific endeavour.

ASSOCIATED DATA OF WILD ORIGIN ACCESSIONS

In a third investigation, we chose to assess the quality of associated wild collected data and its frequency of availability, since this information is, or should be, of great importance to any botanic garden. The quality of information relating to a wild collected plant varies considerably. This has implications on its potential scientific and conservation value (Böcher & Hjerting, 1964; Cullen, 2004). In the present study the same batch of 50 seed lists, were used as in the second study. Three wild collected species were selected at random from each list and an e-mail request made to the appropriate seed bank manager for all associated information. Eleven replies were returned, amounting to information on 33 accessions. In all cases, significantly more data came from this request compared to that published in the *indices seminum*. The data was generally good, although variable, with the majority citing good locality information. A few even had details on accompanying species, although none mentioned corresponding herbarium vouchers. It was however evident that there is no minimum standard for recording data at the collection site.

It would therefore be a valuable initiative to implement standards currently being developed by the European Seed Conservation Network (ENSCONET) to ensure quality and increase the potential uses of seed material. The standards include: country; province/state; locality; latitude longitude; legal documentation; date of collection; collector(s) name; habitat; number of plants sampled; altitude; verification including verifier's name(s) and number; description of material; key accompanying species; area sampled; population size; and herbarium voucher reference. Much of this information is quickly and easily recorded at the point of collection.

Another important finding from the e-mail request for more information to seed bank managers was the element of confusion about what constitutes 'wild collected' seed. This term should refer to material from natural populations. However, four of the 33 accessions confirmed collection beyond the area where they are naturally found. Consequently, these seeds are not from wild populations.

The final part of this study looked at the ease of availability of the associated data. This provided a disappointing finding. We found associated data easy to obtain when we asked. Yet despite this we are confident to say that thousands of wild collected accessions are exchanged each year with no more collection data than that which appears in the printed *index seminum,* despite much more being available by request. Almost without exception, institutes fail to send (or request) all associated data relating to a specific accession. To confirm our assumptions, e-mails were sent to a number of seed banks and to ENSCONET asking what proportion of botanic gardens specifically request full details of data collection. Amongst the replies were typical comments like these:

> *"During the last 4 years only few institutions have asked me for additional information concerning plant origin. If I remember well, they were exclusively European institutions. This is surprising when you think about it, because prior to two years ago we only included name and number in our catalogue" (Piotr Banaszczak, Warsaw Agricultural University Arboretum, pers. comm.).*

> *"We sent about 2,000 seed packages from our index seminum to other botanic gardens last year. From my experience I have to say that only a few requests*

(less than 1%) ask for additional information about collection data. However, this situation is totally the opposite if scientists request seed material for specific projects" (Gerd Vogg, Botanischer Garten der Universität Würzburg, Germany, pers.comm.).

Obtaining this type of information should be fundamental to core principals of botanic gardens. It means that a plant's exact locality and background are known. Without knowing the exact origin of a plant, it is very difficult to draw firm conclusions about any aspect of its taxonomic or systematic status (Rae, 2004). Inadequate standards in record keeping have already been shown to compromise conservation (Maunder *et al.*, 2001) and since relatively few species have been assessed for their threatened nature it would be prudent to assume that all species are at risk until proved otherwise. In fact, a wild collected accession with scant information is probably only marginally more valuable to botanical study than seeds gathered from the garden.

A ROLE FOR SEED BANKS

The role of seed banks enables the majority of spermatophyte diversity to be stored with the possibility of safeguarding a large proportion of a taxa's natural genetic variation in a relatively small volume (see Linington & Pritchard, 2000). The use of seed banks sometimes provokes opposition from fellow botanists. This is normally due to a misunderstanding of its purpose. Storing seeds is not a means in itself, or the guaranteed

Fig. 4 Annual flowers blooming at the Plantenpaleis, Meise. Photo: Frank Van Caekenberghe.

salvation of threatened taxa, but simply a means to an end, to temporarily conserve diversity until a time and place is designated for reintroduction. Seed from these facilities provide botanic gardens with propagation material in order to learn how to grow threatened species and make their successful repatriation more likely. Seed banks also provide samples for research that are normally of tested quality and more documented than those obtained from living collection seed lists or from living plant collections (Thompson, 1970). Such research increases the scientific, and occasionally economic, value of species. In turn, this increases the likelihood that species will be conserved *in situ*.

Putting greater effort into the collection of seed from wild populations, opposed to garden-grown plants, and subsequent banking under long-term storage conditions would enhance the conservation role of botanic gardens and still allow them to participate in a slimmed-down but more targeted distribution of germplasm (Howard *et al*., 1964; Thompson, 1970).

CONCLUDING REMARKS

Given that the core aims of most botanical institutes are research, conservation and education, garden-gathered seeds have severe limitations. Despite this they appear to comprise over 80% of all accessions in botanical seed lists and their frequency is on the increase. It became clear from our studies that some of these accessions are highly ubiquitous taxa that probably do not warrant collection, while other taxa represent some of our most invasive species and flout agreements to control their spread. However, a further concern must be the failure for botanic gardens to ensure that there is a flow of essential data relating to wild collected accessions. This is counter-intuitive to the aims of botanical science and severely reduces the value of those collections to research and conservation. Poor record keeping has compromised conservation in the past, and unless measures are taken, will continue to compromise conservation in the future.

The authors believe that in their present form the cost-benefit from *indices seminum* is low. A significant part of the effort involved could be redirected to improving the quality of the *ex situ* conservation conducted by botanic gardens and the quality of material on offer.

The challenges of conserving our planet's flora have been highlighted for several decades amongst others by botanic gardens. In our opinion, a wise response by our institutes should be to:

- use seed banks more widely to facilitate conservation thereby reducing the risks associated with material collected in gardens.
- use seed banks to supply material offered in seed lists. Carefully review the quality of the material and its documentation before ordering.
- collect and offer mainly wild collected seed using collecting and data standards such as those being developed by ENSCONET.

- prioritise the request and supply of wild-collected seed for research and conservation.
- request all relevant accession information when requesting seed and, where supplying seed, make a greater effort to offer such information.
- offer only short seed lists comprising high quality, verified collections with good standardised data representing relatively few species.
- network with trusted amateurs to aid collection effort.
- organise themselves so that each has a clear conservation (and supply) responsibility for a limited range of species; a central database (hosted by BGCI) would facilitate this.
- think long and hard before deciding what material should be ordered from a seed list. There is always the temptation to order seeds just because they are available.

The reallocation of internal funds to collecting for conservation could significantly aid our contribution to halting species loss and not place the prerequisite of improvement entirely on the shoulders of successful grant applications. However, to gain further momentum botanic gardens do need more funds. To obtain extra money they need the support of policy makers. To obtain this, they need to show that they can operate in an organised way and one which reflects modern management and addresses current problems. The old botanic gardens seed exchange harks back to a bygone age; we should replace it. Botanic gardens may offer one of the few hopes for conserving plants in an age of climatic upheaval. The time has come to meet this challenge.

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APPENDIX 1.

Appendix 1. The number of garden (G), wild (W) and combined accessions recorded for an eight year period. Each year represents 25 randomly selected *indices seminum.* Years refer to the arrival date of the seed list in the NBGB, not the collection date of material.

Year	‘G’ accessions	‘W’ accessions	Combined accessions
2000	15,352	4718	20,070
2001	20,133	5031	25,164
2002	12,610	3682	16,292
2003	13,501	4031	17,532
2004	15,790	3594	19,384
2005	17,729	4259	21,988
2006	11,852	2108	13,960
2007	12,332	1796	14,128
Totals	119,299	29,219	148,518