A Call to Establish a National System of Regional Seed Banks and Seed Networks

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The success of a restoration project depends on many factors, but most critically on the selection of appropriate native plant materials from appropriate genetic sources, on utilizing proper genetic sampling, and on cultivation of propagules. More often than not, the approach to securing appropriate native plant material for restoration and management projects is outdated, flawed, and haphazard. Although large land management agencies such as the U.S. Forest Service, National Park Service, Bureau of Land Management, and some state agencies have their own in-house plant development services, their appropriateness and effectiveness vary widely. Other agencies have no such services, and options are generally much more limited for municipal, state, and regional projects and programs.

Plant procurement for many of these entities is largely dependent on a local patchwork of private-sector nurseries and seed companies in business in a given area and, in many if not most instances, on what materials they have in stock. Some projects utilize custom growing, but generally the seed source is only imprecisely specified, if at all. In New York City, for example, I have never seen a specification that required scientific methods for seed collection, which would ensure good genetic diversity of the source seeds. Furthermore, if collections are initiated only at the time of procurement, one or more additional years may be needed to collect the seed or other propagation materials before plant production can even begin. On a practical level, this means most projects are using restoration materials propagated from seeds or plants already in the hands of nurseries and seed companies, regardless of their origin or appropriateness. If the restoration material is being procured late in project development or implementation—or on an emergency basis—the source of the material may be hundreds of miles away, from very different climates and ecological zones, and may even be from horticultural stock.

In some regions of the country and in some public agencies, there are programs that follow more integrative methods, but these are individual examples that do not yet represent a national trend.[1] I base my judgment on over twenty years of experience, first as an urban land manager and for the last decade as director of a municipal native plant nursery and seed bank. My view reflects the situation that I perceive in the urban Northeast and may differ considerably from opinions of those in other regions and at other levels of government. However, I think readers from across the United States will benefit from the practical recommendations I present here. Indeed, it would be a worthwhile outcome of this paper if readers responded by citing other well-formulated programs. It is my hope that this article will open up a broader discussion of seed and plant procurement policies since there is a critical need for initiatives that will lead to improved practices.

Efforts to plan systematically for future seed needs mostly come from large federal agencies such as the U.S. Forest Service or Bureau of Land Management. For instance, the Forest Service requires "each National Forest to develop and implement a Ten-Year Procurement Plan" for tree species (USFS 1998). I am aware of only one such effort at the state or municipal level, although others probably exist but are not well documented and are difficult to survey.[2] It would seem that the role of the public sector in securing genetically appropriate source material is not as widely considered as it should be. Furthermore, the examples that I am aware of are not all well coordinated to ensure that appropriate plant material is available when needed and in the quantities required by the projects and programs served.

There is extensive scientific literature documenting the importance of protecting the amount and integrity of genetic diversity in local plant populations from the introduction of novel genes via restoration materials. The significant negative consequences of these translocations have been demonstrated in principle and are excellently summarized in Hufford and Mazer (2003), Rogers and Montalvo (2004), McKay et al. (2005), and others.

There are two concerns regarding the appropriate choice of plant materials for restoration: (1) the likelihood of success of the project, and (2) the impact on neighboring native plant populations, if any. Regarding the latter concern, if many plants are used but represent only a small amount of genetic diversity—for example, if there are cuttings from one plant or clone—they could cause over time the genetic diversity in neighboring populations to decline (this is called genetic erosion). Alternatively, if the restoration materials were not well adapted they could, nevertheless, undermine the adaptations of nearby natives over time.

Scientifically Sound Methodologies

Selecting genetically appropriate sources for restoration materials is not a simple undertaking. Furthermore, the process differs depending on the management objectives and the size and context of the restoration project (e.g., vast landscape vs. small urban area). Rogers and Montalvo (2004) suggested a methodology for selecting genetically appropriate source material for a project site, utilizing a ten-step decision tree applied to each species under consideration. Johnson and Roy (draft) have attempted to simplify this process by utilizing a Genetic Effects Rapid Assessment Matrix. Both of these methodologies attempt to tackle the pragmatic dilemma project managers face of how far they can go off-site for plant material without genetically compromising on-site and adjacent plant populations (a so-called safe seed-transfer zone). Ultimately, a practitioner applying these methods could arrive at some definition of an acceptable seed-transfer zone or seed-transfer strategy for each species in that particular project, leading to some a reasonable assuredness that they have answered their question and protected their resources. (In highly urbanized sites with no biological connectivity between populations, land managers may not need to go this far. Ensuring that proper seed collections for genetic diversity have been made from locally adapted seed sources may be enough to ensure long-term sustainability of their restoration and management efforts on genetically isolated populations. However, they will still need to be concerned with the effects of those translocations on any extant remnant populations.)

In order to construct seed-transfer zones, and in the absence of direct genetic information about species selected for restoration, both the Rogers and Montalvo (2004) and Johnson and Roy (draft) methodologies utilize ecological, life history, and other biological species data. Much of this data is not easily accessible to non-academic project planners, or may not yet exist. To apply either of these methodologies on a species-by-species basis for all of the species intended for a project would, in most instances, exceed the time constraints that virtually all projects face. Rogers and Montalvo (2004), among many others, wisely counsel that sufficient lead time for planning is crucial if these issues are to be addressed. For many projects, this is a luxury rarely enjoyed. A project planner or manager looking to apply these methods while working unaided would find it hard to assemble sufficient information to make critical seed source choices. Those with access to academic resources may find it less problematic. In any case, even if they could successfully perform these evaluations, the lead time needed to collect the proper seed may already have passed.

We need to begin to come to grips with the complexities of these issues, propose steps to take, and reach pragmatic solutions to their implementation. I believe that in building upon the foundation of existing programs we have the means of implementing the necessary policies, practices, and bureaucratic frameworks to do so.

Practical Alternative Solutions

So how might we reasonably approach these issues and take positive steps to resolve them? I submit two proposals for consideration. Both advocate for regional efforts and a strong public-sector role.

First, as a pragmatic solution that would result in immediate improvements, I propose a national system of regional active seed banks to dramatically increase availability of local seed. Second, I propose the simultaneous establishment of regional seed networks—geographically identical in scope to the regional seed banks—to address the issues of seed-transfer zones and to provide a bureaucratic framework for regional cooperation and cost sharing. These proposals are diagrammed in Figure 1.

Regional Active Seed Banks

Initially, in the absence of seed networks and local seed-transfer zones (which arguably would take time to establish and yield practical results), we can still vastly improve upon most current seed-procurement practices by investing in regional seed banking. In this scenario, practitioners would not yet employ the complete methodology of Rogers and Montalvo (2004) or Johnson and Roy (draft) to select seed source for their project. (I would still recommend that project planners familiarize themselves with them, as they are crucial next steps in evolving appropriate strategies.) They would, however, make use of sources as close to their project site as is practical and would exercise much greater control over the process. This conservative approach is perhaps the closest approximation for the moment to the Rogers and Montalvo (2004) methodology and a clear improvement over the largely random process that currently exists in many places.

Let me first distinguish between active seed banking and long-term or conservation seed banking. Conservation seed banking is what most of us think of when we hear the words "seed bank." In this scenario, seeds—most commonly of species of conservation concern—are dried to low relative humidity, hermetically sealed, and then stored at low temperatures (typically -18°C) as a hedge against their loss in natural habitats. This has been commonly referred to as a "Noah's Ark" approach to conservation. Facilities to store this seed safely, for perhaps hundreds of years or longer, cost in the millions of dollars, and are mostly run as national or international institutions. Two examples are the Millennium Seed Bank Project (MSBP) of England's Royal Botanic Gardens, Kew, and the USDA National Center for Genetic Resource Preservation in Fort Collins, Colorado.

Active seed banking entails a shorter storage period, under similarly low relative humidity conditions, but at only moderately low temperatures (5–12°C), which guarantees seed viability for perhaps decades at a time, long enough to serve the needs of supplying local restoration and management projects. Costs for these types of facilities are much more modest than those of conservation seed banks. At the Greenbelt Native Plant Center in New York City we have established, with the aid of MSBP, an active seed bank at costs only in the tens of thousands of dollars. The purpose of establishing such a facility is much more analogous to a true bank, where seed can be withdrawn by depositors as needed. [See Cromarty et al. (1990 revision) and CPC (1994).]

What would a regional seed banking effort look like? First, collections would be made only by properly trained technicians to make certain that the maximum genetic diversity of a population is being captured in the collection and that established collecting protocols, such as those from the national Seeds of Success (SOS) program, are followed. Second, collections would be accessioned, entered into a database, and maintained individually so that the seed bank would truly be a repository of local collections that could be utilized for local projects. In this way, seed could be collected and stored in preparation for specific local projects, to be withdrawn when the time came to begin propagation. This would go a long way toward enabling the use of local seed by ensuring a ready supply. (Once the seed bank is in place, local agencies and organizations would also be better motivated to plan ahead for future needs, since a clearer pathway to implementing sound practices would be in place.) Seed would be collected only for the specific projects and programs that have partnered with the seed bank, and the banked seed would be theirs. The partners themselves would then provide their seed to commercial nurseries and seed companies to contract grow for them, and not for general sales or release. With the costs of collecting, processing, and storing shared regionally among all of the partners in the seed bank, costs could be kept relatively low, and individual agencies or organizations within the region would not need to invest in the staffing and infrastructure required if doing these tasks alone.

Such efforts must be properly managed so that these resources are neither squandered nor misused, and collection is not detrimental to source populations. Seed must also be fairly distributed to partners. Methodology must be developed to anticipate future needs far enough in advance so that the necessary seed resources are available and can be provided to the facilities, largely in the private sector, that will produce the required plant materials for the specific projects and programs. This last step must also be within a controlled and monitored framework that guarantees the verity of the plant and seed end products. The public sector should control the seed resources of a region, seeing to their conservation and effective utilization.

On a national level, I am aware of two large-scale government efforts that could form the basis of a system of regional active seed banks. The current network of 26 participants in the national Seeds of Success program, with their regional expertise and population-genetics-based approach to seed collection and conservation, could act as the national base for this program, to which more regional partners could be added as needed. Already aggregated since 2001 into a national framework of cooperation, their relationship is soon to be formalized in a memorandum of understanding and their national role expanded.

Additionally, there are the 27 regional Plant Material Centers of the USDA National Resource Conservation Service. Although their history and mission lie in plant improvement and selection, including that of native species, their substantial knowledge of plant genetics, seed collecting and banking, seed technology transfer, and the production of source-identified seed would make them invaluable partners in this effort. Their mission would need to be expanded to function as regional active seed banks, or, if not, then to assist others with their various areas of expertise. I would strongly advocate that such possibilities be explored.

As many as fifty or sixty well-trained centers drawn from these two sources, or newly formed by others, could easily form the nucleus of a nationwide network of regional active seed banks, each focusing on its individual area, but certainly drawing synergistically on the effort of the others.

The Greenbelt Native Plant Center has recently taken steps to offer our active seed bank as a regional resource. We are working with groups on Long Island and in the Catskill region to collect cooperatively and bank their local seed resources for future use. We anticipate continuing to expand on these efforts.

Regional Seed Networks

As useful as a national system of regional seed banks would be, I envision their creation as only a pragmatic first step. The concept should be expanded to include regional seed networks. These networks would serve as a bureaucratic framework for interorganizational management of the region's seed resources and seed bank and would also pool the scientific and technical expertise of the region to address seed-transfer zones and any other scientific or technical issues as they arise.

Through a regional seed network all of the interested parties could come together, discuss their needs, issues, and limitations, and give shape to a cooperative effort. In this way, the region's seed resources could be managed so as to conserve them and to provide an adequate and timely supply of local seed to meet the cooperator's needs. Ideally, all of the relevant local, state, and federal agencies together with the principal nongovernmental organizations (NGOs) that are jointly responsible for most of the restoration and management activities in the region should be encouraged to participate in the regional seed network as members. This is critical in several respects—first, in building a comprehensive picture of the region's seed needs; second, to cost share the seed banking operational expenses among as many partners as possible, lowering the cost for each participant; and third, to make sure that most of the region's seed resources, which in many regions of the country are largely on public lands or locked up within private conservancies, are accessible to the seed bank for collection and storage. Such an arrangement would be formalized as a memorandum of understanding between all of the participants. A collection MOU should include provisions for environmentally sensitive collection practices and ways of sampling seeds/propagules to ensure good genetic representation in the samples. The networks would meet periodically to set policy and discuss larger organizational issues. To streamline operational decisions, a more limited governing council would be appropriate for more regular meetings.

So that a realistic assessment of seed needs can be made, I propose that a regional registry of projects be established. This would be a definitive list of network cooperators' planned projects and/or ongoing management needs over the next five to ten years, with information about species, quantities, projected start dates, etc. This information would be critical to planning and staging seed collection operations for the region and guiding the regional seed banks about where to concentrate their efforts, and would be continually updated. The network and its governing council would also prioritize collections, setting target species and determining the most critical needs.

The seed networks would pool regional resources to establish protocols and assemble the information needed to determine local seed-transfer zones within the region. Pooling from the region's universities, colleges, botanic gardens, arboreta, natural heritage programs, NGOs, plant societies, and even interested, trained, and skilled volunteers outside of these institutions, the networks could assemble teams to work on various aspects of the scientific and technical questions that need to be answered to start to assemble seed-transfer zones. Pertinent questions involve an understanding of breeding systems, mating systems, ploidy states, and the like for each species. Some of the necessary information would be found by compiling existing literature. Some questions might entail research, such as common garden studies, which could be the basis of academic research or thesis projects. As a body of knowledge is assembled on the species found within the region, these scientific committees would be in a position to write species-specific protocols and perhaps even to make some generalized recommendations along the lines of Johnson and Roy's Rapid Assessment Matrix or as best management practices. A sidebar to this paper contains useful starting points for how to go about the process of assembling this information.

To aid these regional efforts, and because many species will be of common interest from region to region of the country, I further recommend the establishment of a national database as a repository for all of the species-specific ecological genetics data needed to make seed-transfer zone decisions, an idea already proposed by Rogers and Montalvo (2004) in chapter ten of their work. As this information is acquired, it would be added to the database for anyone to access. This would avoid time-consuming duplicated efforts and would greatly facilitate utilizing either the Rogers and Montalvo (2004) or Johnson and Roy (draft) methods. Such a database could be part of the USDA PLANTS Database website (plants.usda.gov) or could be hosted by a national organization such as the Plant Conservation Alliance. An example of the types of information that should be part of the database is found in Tables 10.1 through 10.8 of Rogers and Montalvo (2004).

As an example of a local initiative, the Greenbelt Native Plant Center has begun a collaboration with the science staff at Brooklyn Botanic Garden and plant ecologists from the NYC Parks Department in an effort we are calling the New York City Native Plant Conservation Initiative. We plan to map extant plant populations and examine the degree of biological connectivity among them (particularly which of these populations are within effective pollen and seed dispersal distances). Based on this analysis, we will determine protocols, including possible seed-transfer zone recommendations, for the management and long-term health of these populations. We will also be looking at whether opportunities exist within the urban matrix to increase the connectivity of some of these populations. Ultimately, seed-transfer zone decision making for any project or program will have to take place at a similar local level of individual restoration and management projects, but the information and groundwork done at a regional level will greatly facilitate the task.

I reiterate that, for the successful implementation of these recommendations, the products of these efforts, most concretely the regionally banked and reserved seed, must be shared and available to all interested parties, including the private nursery and seed industries, in a manner that is equitable while at the same time protective of the seed and genetic resources. Even well-documented and banked material can be deployed in an inappropriate way, and it will be important to educate seed network members to handle seed deployment appropriately.

Clearly the establishment of networks and seed banks and the support of their operations will require substantial funding. But the need is real, the payoffs are monumental, and the consequences of ignoring these issues any longer are too devastating, as our ecosystems face the cataclysmic consequences of biological invasion, climate change, habitat fragmentation, and irreversible harm to the genetic integrity of local plant populations. The time to act is now. We have considerable resources to begin the process, and we can build from this base.

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Endnotes

[1] See, for example, the Los Angeles River Master Plan Landscaping Guidelines and Plant Palettes at http://ladpw.org/wmd/watershed/LA/LAR_planting_guidelines_webversion.pdf; the Native Seed Network in the Willamette Valley in Oregon; and also the Iowa Ecotype Project.

[2] The California Department of Forestry and Fire Protection collections from California tree seed zones on about a ten-year cycle. See: http://www.fire.ca.gov/ResourceManagement/PDF/Nurseries.pdf.

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Sidebar: Obtaining Genetic Information on Native Plants Useful in Restoration Decisions

Information about the ecology and genetics of many species of plants can be found in academic, applied, and government publications online as well as within existing online databases. When direct genetic information is not available, some information on a plant's characteristics (such as its breeding system, life form, and means of dispersal) can offer insights into its genetic characteristics. For example, the Fire Effects Information System (FEIS) database provides extensive reviews of the general biology, ecology, and relationship to fire of nearly a thousand plant species. Many of the reviews contain some basic information important to selecting sources of plants, including information on life form, elevation, habitat affinities, regeneration after fire, geographic distribution, taxonomic synonyms, and establishment.

There are a number of valuable search tools and databases available to the public to search for information on individual species. College, university, and botanic garden libraries are excellent resources for online and hard-copy publications. Much published literature is available online outside of libraries and can be found with the help of electronic search engines designed to find papers published in the scholarly literature. In addition, much of the literature cited in a database search is now available online.

Where to begin?

When starting a search, one place to begin is the USDA PLANTS Database. This resource provides standardized information about the vascular plants, mosses, liverworts, hornworts, and lichens of the U.S. and its territories. The database is searchable by scientific or common name and provides taxonomic synonyms, plant distributions, wetland status, and links to a variety of databases. Also consult the Integrated Taxonomic Information System to check on nomenclature. The online version of the Flora of North America, although not complete, may also be consulted for recent taxonomy and distribution information for many species. The list of synonyms generated from this exercise is important because much important ecological genetic information can be found in older publications when a search includes older plant names. The FEIS database also includes synonyms as well as basic information on botany and fire ecology.

It is also useful to consult local floras whenever they exist. Some are online—for example, the New York Flora Atlas. Some floras include information about the ecology, cytology, geographic distribution, and if there is substantial morphological or known genetic variation within species. Each state may also have information on rare plants, and native plant societies sometimes publish useful information. For example, the website for the California Native Plant Society Rare Plant Program publishes its Inventory of Rare and Endangered Plants online, as does the Colorado Natural Heritage Program.

For a detailed search, you can pair names of species with keywords or phrases for the type of information desired. Some useful keywords and key phrases include:

1. Reproductive mode, natural regeneration, soil seed bank, seed dormancy, seed longevity,

resprouting (for regeneration capability after fire, flood, or other damage)

2. Clone, rhizomes, asexual propagation, asexual reproduction

3. Seed type, seed morphology, seed dispersal mechanism

4. Life-history, parity, annual, perennial, biennial

5. Pollination, pollinators

6. Gene flow, pollen dispersal, seed dispersal

7. Breeding system, mating system, selfing, outcrossing, mixed mating

8. Ploidy, chromosome number, cytotype

9. Local adaptation, population differentiation, geographic variation, population structure

10. Inbreeding depression, outbreeding depression, inbreeding, outbreeding, heterosis

11. Hybridization

Detailed searches of species names and topics can be made using online search engines. Google Scholar is available to all, and though not thorough, can come up with some useful information. Most botanic garden, university, and college staff and students have access to a variety of journals online through their libraries and to powerful searching programs such as BIOSIS, AGRICOLA, CAB Abstracts, Digital Dissertations, and Web of Science. USDA employees have access to most of the library search programs through DigiTop on the website of the National Agricultural Library.

Once your citations are found, the text can often be found online. All volumes of over a dozen botanical journals (including the *American Journal of Botany*, *Applied Vegetation Science*, *Ecology*, *Systematic Botany*, and *Systematics and Geography of Plants*) and two dozen ecological/evolution journals (including *Conservation Biology, Ecological Monographs, Evolution*, and *American Naturalist*) are available online from JSTOR, an Internet archive for scholarly journals. JSTOR journals can be searched from the JSTOR site by typing in plant names, title words, keywords, or phrases into the search queries. A list of citations will appear, and the papers can be accessed by clicking on the citation. The JSTOR site provides lists of institutions and agencies that have subscriptions (including many public libraries, education institutions, and agencies), and individual subscriptions can be obtained easily. In addition, many professional societies and publishers of journals, including most genetic journals, have made issues available online with a subscription. Some, such as the *The Journal of Range Management*, make back issues available without a subscription. E-journals.org lists a database of online botanical journals. Botanical gardens are also great resources for information. Brooklyn Botanic Garden's website provides links to its library and herbarium resources and information about its library resources.

Online Resources

Atlas of the Vascular Plants of Utah: www.gis.usu.edu/Geography-Department/utgeog/utvatlas

Brooklyn Botanic Garden: bbg.org

California Native Plant Society Rare Plant Program: cnps.org/cnps/rareplants

Colorado Natural Heritage Program: cnhp.colostate.edu

E-Journals, Electronic Sites of Leading Botany, Plant Biology, and Science Journals:
e-journals.org/botany/

Fire Effects Information System:
www.fs.fed.us/database/feis

Flora of North America:
hua.huh.harvard.edu/FNA/volumes.shtml

Grass Manual on the Web:
herbarium.usu.edu/webmanual

Integrated Taxonomic Information System:
itis.gov

JSTOR: www.jstor.org

National Agricultural Library, DigiTop:
nal.usda.gov/digitop

New York Flora Atlas: atlas.nyflora.org

USDA PLANTS Database: plants.usda.gov

U.S. Forest Service Native Plant Materials Policy and Authorities:
www.fs.fed.us/wildflowers/nativeplantmaterials/policy.shtml

Figure 1: Flow chart showing relationships among all proposed entities and activities in the native seed procurement and production equation.