General Considerations for Growing

Native plants are cultivated for seed production in order to concentrate the desired plants in a small convenient area, and to enhance their seed production through soil management and weed control. But there is always the danger that this process will result in the active or passive selection of plant genotypes well suited for growth in cultivation, but perhaps less suited for growth in the harsh and competitive environments of revegetation sites. Consequently, it is recommended that the entire program of native plant husbandry incorporate conscious efforts to protect genetic diversity:

- plant material from diverse locations and habitats should be employed;
- efforts should be made to encourage outcrossing ("cross-breeding" of populations within a species);
- infusions of new wild stock should be added to producing fields;
- every effort should be made to coax all plants into production; and
- seed should be saved from even the smallest and apparently inferior genotypes.

Genes of plants that may not grow the tallest or produce the most seed are still important in the wild if they confer drought tolerance, disease resistance, and so on. In order to grow native plants on a long-term basis, and not just domesticate them, the grower must always have the maintenance of genetic diversity in mind.

Most of the species described in this manual are perennials. They typically require a year or two for establishment before they produce significant quantities of seed. After a slow start, they are generally quite persistent and will continue to produce seed for three years or more. During that time, weed control will be the biggest challenge to most seed growers. Perennial crops are not tilled under and re-established every year, so weeds aren't killed by cultivation on a regular basis like they might be when farming annual crops. One of the main purposes for using native plants in revegetation is to avoid the introduction of exotic species, so there is "zero tolerance" for the spread of noxious weeds with native plant seed. The presence of all non-crop species also inhibits the vigour and seed production of the desired species. Careful field selection and preparation, followed by vigilant weed control, are key to the success of any commercial seed growing effort.

Though native plant seed is usually applied in mixtures when used for revegetation, reclamation, and ecosystem restoration purposes, that seed is best grown in single-species stands. This makes "weeding" and monitoring of the crop easier, and harvesting more efficient. Seed from several species can then be combined later in the precise proportions desired for particular land uses or microsites (as described in later sections).

<u>Site Selection and Preparation</u>

There are two schools of thought when it comes to the selection of a location for establishing seed production fields of native plants species: (1) to use rich fertile soils as one would any other crop; or (2) to use marginal soils that more closely match the sites that are intended for revegetation using the seed being grown there. If seed production is the goal, and if concerted efforts are made to maintain genetic diversity, it quickly becomes apparent, however, that good cropland is preferable. Soils should be loamy, or sandy if irrigation and fertilization are options. Deep soil free from topographic variation and stones will make mechanical operations much easier and the crop more uniform in its development.

More important than soils are the weed populations and history of a field being considered for native plant seed production. Ideally, a field would be completely free of non-native species before being employed in native plant seed production, but this is rarely an option (perhaps only on recently broken land). Consequently, it is strongly recommended that fields be fallowed for two years and subject to rigorous weed control prior to stand establishment. Locations infested with noxious weeds such as quackgrass (*Elymus repens*, also known as *Agropyron repens*) or Canada thistle (*Cirsium arvense*) must be especially avoided. These perennial weeds tend to be abundant in former hay fields and pastures, so land that was previously used for cereals or other annual crops is generally preferable.

Pre-planting weed control is best achieved through a series of repeated control operations conducted throughout the growing season. When dealing with annuals and non-rhizomatous species, repeated cultivation (to uproot plants, and expose a fresh batch of weed seeds to surface conditions that prompt them to sprout) seems to work best. For example, a field might be disked or cultivated early in the season as winter annuals start to green up and flower; after they are turned under, it might be another two or three weeks before the fallow greens up again from a new crop of annuals. It is then time to cultivate the field again, killing those seedlings by exposure or burial, and prompting a new bunch of seeds to germinate; this should continue until the soil's bank of weed seeds is depleted. Perennial rhizomatous species are not so easily dislodged, and generally must be treated with systemic herbicides such as Roundup™ or other product containing glyphosate. One problem with the chemical approach, however, is that it only works on green plants, and does not address the seed bank or dormant rhizome fragments inevitably found beneath the surface. Another alternative is to use large sheets of black plastic as a ground cover, heating the ground and cooking any weeds growing on the surface; furthermore, it prompts a number of weed seeds to germinate, after which they die in the darkness under the black plastic. Experience has shown that black plastic treatments, like other control efforts, generally have to be applied for two growing seasons (especially on former hay or pasture lands) in order to bring weeds under control. Whether by mechanical or chemical means, it is important to kill all weeds before they produce another crop of seeds or another generation of underground rhizomes.

It is generally considered that a well prepared but firm soil is best for growing any crop. Seeds of many of the species described in this manual are very small and as such have low food reserves. This means that the seedbed should be finely cultivated and smooth, and that sowing should not be too deep if establishing these species from seed. A recommended procedure is to disk or cultivate the field first, followed by repeated harrowing; alternatively, repeated rototilling can prepare a fine uniform seedbed. A firm seedbed conserves soil moisture, and enables the seed to make good contact with the soil, thereby enhancing the likelihood of successful germination (Pahl and Smreciu 1999).

Stand Establishment

Seed increase plots and seed production fields can be established in three main ways: transplanting greenhouse-started plants; manually sowing single rows; or mechanically sowing multiple (usually closely-spaced) rows. In all cases, provisions should be made for convenient weed control and harvesting. The first option, usually employed when starter seed is in short supply or its germination unreliable, is to start seedlings in a greenhouse and then transplant individual seedlings out into garden plots, usually arranged in rows for ease of weed control and harvesting (Figure 1). Seedlings can be started in open flats, or in containers; containers such as Styroblocks™ have the advantage of keeping root systems of neighbouring plants separate, and the root system forms a "plug" that is easily transplanted. Seed can be started in any sterile greenhouse rooting or potting medium, consisting of some combination of peat moss and vermiculite, perlite, or sand. Seeds and seedlings are typically watered one or more times per day, fertilized once or twice a week with an all-purpose (high N-P-K plus S and micronutrients) plant food, and temperatures are monitored and venting adjusted accordingly to make sure that seeds and seedlings aren't heat-stressed.

Figure 1. Transplanting greenhouse-grown grass seedlings into a seed-increase plot.

Seed production plots or fields can also be started from seed, either in single or closely paired rows (Figure 2), or in tight stands (usually on a larger scale, Figure 3). Seed generally needs to be well cleaned and detached from any appendages (fluff and awns) or mixed with an inert carrier (such as cracked wheat, cat litter, or fertilizer) so it will "flow" well in the seeding machinery. A manual single-row seeder (Figure 2) does the job for most small-scale production areas. Sowing depth and density are easily adjusted, and peat moss, sawdust or loose soil can be manually scattered over surface-sown seeds. Rows are typically spaced 80 to 100 cm apart in order to allow room for weed control (e.g., rototilling) and maintenance access, and will also promote more vigorous growth than in dense stands. Rolls of plastic or paper mulch between rows can be an effective weed deterrent, but manual weeding within the rows will usually still be required.

Figure 2. Fall-sowing a native forb using a single-row (Planet Junior™) push seeder for establishment of a small seed production field. Row spacing here is approximately 80 cm, with strips of old vinyl flooring later rolled out between rows for weed control.

Mechanical sowing (Figure 3) is also an option for most species. Specialized precision equipment suitable for small-scale plot production is manufactured by companies such as Kubota™, Almaco™, and Wintersteiger™, but older small farm equipment for sowing, cultivating, and harvesting will often be adequate. Seed drills should be equipped with press wheels or the ground should be packed after seeding, except on heavy clay soils. The depth of seeding should never be greater than twice the longest diameter of the seed being sown; this means the small-seeded species are just spread on the surface and then lightly pressed into the loose soil. The use of a carrier to bulk up volumes and to improve seed flow in seed drills may be necessary (especially with the chaffy and hairy species). Seed carriers include cracked or roasted grain, vermiculite, and cat litter (Pahl and Smreciu 1999). Commercial fertilizer has also been used as a carrier, but questions remain about the advisability of having high concentrations of fertilizers (and their salts) immediately adjacent to germinating seeds. Fertilizers can also be highly corrosive to machinery if its dust is not carefully removed from the equipment (typically using a vacuum cleaner or compressed air stream) after use.

Figure 3. Spring-sowing a native grass using a small (Brillion™) seed drill pulled by a tractor for establishment of a small seed production field. Row spacing here is approximately 12 cm.

Where feasible, irrigation during the crop establishment phase is a good idea. Most developing seedlings will not tolerate drying, and this is the most vulnerable stage in seed crop stand management. Irrigation can continue until the flowers are ready for pollination; Pahl and Smreciu (1999) recommend that irrigation be stopped then and during seed ripening, although irrigation may resume temporarily during early seed development. In our experience, *Rhizobium* innoculant to stimulate the formation of nitrogen-fixing nodules in legumes is unnecessary on agricultural soils.

Stand Maintenance

Weeding is usually the main stand maintenance activity. Manual weeding by pulling or hoeing is the norm, with mulching or rototilling between rows. Once plants are well established and are mature in size, careful placement of deep straw or other mulches can greatly the need for weeding, which is very labour-intensive. Sometimes selective herbicides can be used: for example, dicotyledon weeds can be killed by broadleaf herbicides such as 2,4-D or Banvel™ (active ingredient dicamba) if the crop is a grass. But even though grasses and sedges are not killed by these chemicals, they can sometimes inhibit seed production, and these chemicals are all somewhat toxic to animals and humans. Spot-spraying with glyphosate (e.g., Roundup™) is another option, utilizing a backpack sprayer or spray bottle. A shrouded nozzle or a sheet of rigid plastic or plywood can serve as a baffle to protect adjacent crop plants. If a young stand is being over-run with weeds, one can sometimes "cup" all crop plants with upside-down plastic containers, and then broadcast-spray all weeds with glyphosate or other broad-spectrum systemic herbicide. Even large fields of native plants should still be walked to remove non-crop species, especially the exotic and noxious species that produce seed that would contaminate the seed crop.

To promote stand vigour and seed production, it is generally recommended that seed production plots and fields be fertilized. The appropriate fertilizer formulation and its rate of application will need to be adjusted depending on the species and the condition of the soil; soil testing should be conducted to determine deficiencies. For example, forb plots should be fertilized with a balanced fertilizer when plots are first established and annually thereafter. Grasses do not need excessive nitrogen (N) as this will encourage vegetative growth and lower seed yield. Nitrogen-fixing plants may not need nitrogen but will need other nutrients (Pahl and Smreciu 1999). Though high N supplements may be called for in the soil test results, this should only be done while the plants are in an early vegetative phase; higher ratios of phosphorus (P) and potassium (K) to N should be utilized in early to middle summer to promote seed set and filling.

With the exception of *Collinsia parviflora*, the plants listed in this manual are all perennials. It appears that some species (e.g., *Arnica* and *Aster* spp.) may be long lived, but others (e.g., *Festuca occidentalis*, and *Achillea millefolium*) have a relatively short life span (under 3 years) as seed producers, but the productive life span of most species still remains unknown. Weed control, fertilization, and stand rejuvenation through clipping and thatch removal can prolong stand life, but not indefinitely.

Mowing grass plots immediately after harvest and removing any post-harvest residue from forb plots are recommended to help reduce disease and insect problems. This procedure increases light and heat to the plant root crowns at the beginning of the next growing season. Remove weeds routinely before they go to seed in order to keep plots weed free, and the reservoir of weed seeds in the soil will eventually be depleted.

Where specific information is available for particular species, variations to these stand management recommendations are presented below in the individual species accounts. Much still needs to be learned about stand maintenance and the optimal timing for stand replacement. Growers are urged to try various management regimes (especially related to fertilization routines) and to keep records of stand maintenance practices, so this information can provide improved guidance for producers in the future.

Harvesting

Wild plants, by definition, have not been selected for uniformity of ripening time, which has been one of the first steps in the domestication of many of man's crop plants. As a result, the seed in stands with broad genetic diversity typically ripens over a long period of time, with some seed heads over-ripe and losing their seeds to the ground before seed on other plants is ripe yet. So the careful timing of harvest, and approaches to repeatedly and selectively harvesting a stand, are important elements of the successful production of native plant seed. Given the threat that seed stocks might be contaminated with exotic species, it is also a good idea to rogue out all undesired seed heads (of weeds and other non-crop species, and those that might be diseased) from the stand prior to harvest to avoid seedlot contamination.

Depending on the species, harvesting may entail the stripping of seeds from seed stalks in the field, or the entire removal of those seed stalks and heads for threshing. In both approaches, the challenge is to glean ripe seeds efficiently from the plants without scattering the valuable seed to the ground and losing it. The harvesting methods detailed in this publication are primarily manual and small-scale mechanical approaches. Sharp hand sickles are very effective for harvesting most grasses and sedges (Figure 4), while sharp clippers work well for other species. A scythe may also be appropriate for some grasses, but we have no experience from which to draw in that regard. Seeds can be harvested selectively as they ripen but this is time-consuming and eliminates any possibility of mechanical harvest. Placing plastic between rows early in the season will not only help to control weeds but also permits harvest of the seed crop when the bulk of it is ripe. Seeds that ripen early will drop onto the plastic and can be later vacuumed up, so long as they are not contaminated with weed seeds. So it is a good idea to sweep or vacuum the plastic to remove dirt, debris and other contaminants just before the crop starts ripening.

Figure 4. Harvesting *Calamagrostis canadensis* seed from a seed increase plot using hand sickles.

Small seed increase plots do not warrant the expense of combine harvesters, though seed production fields much greater than 0.2 ha might be harvested with such equipment if available. Recommended settings for the rotation speed of the combine cylinder head in rotations per minute (rpm) and concave spacing (in mm) are therefore provided with the individual species descriptions. Mechanical harvesting is especially suitable for most of the large-seeded grass and sedge species, and where large quantities of seed are being harvested on a regular basis. For plots intermediate in size, a hand-held seed stripper (Figure 5) can be used (Morgan and Collicutt 1994; see also www.prairiehabitats.com). While this method is especially useful for harvesting some seed from wild stands, we found it was not efficient for salvaging all the seed being grown in plots, because much of the seed was scattered by the stripper strings rather than being scooped into the hopper. Therefore, if using a seed stripper, make sure there is cleanly swept plastic between the rows so that scattered seed can be salvaged with a vacuum or broom.

Figure 5. Harvesting *Elymus glaucus* seed from a seed increase plot using a motorized seed stripper.

If one has access to electricity or a generator, a shop vacuum works extremely well for harvesting the species with fluffy seeds. A modified gas leaf blower is also available at a reasonable price, but its suction is not as good as that of a shop vacuum. There are also industrial vacuums and sweepers (such as various Toro™ Flay-O-Vac and Rake-O-Vac models) that can be pulled behind a tractor, but these are expensive. Modifications that combine sweeping and vacuuming action (also expensive; e.g., the Woodward Flail-Vac™ system; see www.ag-renewal.com) may represent the ideal compromise for harvesting field-grown wild seed. Flail-Vac heads range in width from 1.2 m to 3.6 m, and are mounted on front-end loader arms fitted to all-terrain vehicles (ATVs) or tractors. Technology that combines sweeper and vacuum action is generally flexible enough to be applied to a variety of species, and can be used repeatedly on the same stand for selective harvesting as seed ripens.

As mentioned above, seeds of wild and genetically diverse cultivated plants typically do not ripen uniformly, so this must be taken into account when harvesting. When using manual and vacuum harvesting methods, repeated passes of the seed production area every few days will allow most seed to be collected rather than lost. For seeds that are held more tightly to seed heads, it is often most practical to cut the entire crop at one time, and to then dry or cure it under warm dry conditions, thereby allowing much of the green or soft seed to fully ripen before threshing. Hand-clipping, sicklebar mowing, or swathing should be done before a significant amount of ripe seed falls and while some seed is still green or soft. Seeds can be efficiently dried in the sun if the weather co-operates. This step essentially allows the younger seeds to "catch up" in their process of maturation without losing all of the more mature seed. On a large scale, this is done by swathing the stand before threshing or combining it (Figure 6); on a smaller scale, sheaves (bundles) of seed stalks can be spread to cure on large tarpaulins or plastic sheets, or on clean concrete floors in the shelter of a warehouse or shed (Figure 7). Losses to mice and voles can be a problem, so mouse traps may need to be set, and drying times should be kept to a minimum (generally a few days to a couple weeks). Once dried, seed should be threshed immediately. If immediate threshing is not possible, seed heads or seed stalks should be stored as sheaves, or loosely in paper or breathable seed sacks, so that any remaining moisture can escape and the seed won't mold.

Figure 6. Swaths of *Elymus trachycaulus*, curing on the ground prior to threshing.

Threshing and Cleaning

Like harvesting, threshing and cleaning can be done by a range of manual and mechanized approaches. Old farm machinery can provide an economical means of harvesting, threshing and cleaning native plant seed, though modifications and relatively large quantities of seed are typically required. Seed is usually somewhat threshed (removed from seed stalks and seed heads) in the harvesting process, and more seed usually falls off during handling. It is important to salvage this seed, which is made easier by working on clean, sweepable concrete surfaces. Further seed removal can be done by hand-stripping, or by a variety of mechanical beaters or flails. For very small quantities, placing seed heads in a closed container with a hard rubber ball and shaking vigorously can serve to dislodge seeds; this can also be done in conjunction with small-scale seed cleaning conducted with soil sieves.

Figure 7. Grass seed stalks spread out for drying and curing (ripening) in a warehouse.

Symbios Research & Restoration uses two machines for mechanized threshing, both mounted on stationary stands and powered by 373 to 736 watt (½ to 1.0 hp) electric motors. One is a custom-made rotary flail, consisting of 10-cm lengths of bolted pipes between four steel disks (12 cm radius) mounted on an axle and housed in a cowling that directs seed downwards (Figure 8). Seed stalks are held by hand in large clusters, with the seed heads inserted into the flail until all or most seeds are removed by the beating action. Care must be taken that heads are never inserted so far that they get wrapped around the axle, and that hands are not drawn into the machine (wearing strong, loose work gloves and eye protection is essential).

If the resulting seed stock still contains a number of full or partial seed heads with seeds attached (as often happens for some grass species), seed may be run through a second machine called a rethresher. A rethresher is like a miniature combine harvester, consisting of concave-grooved bars attached to a heavy flywheel that can be run at different rotations per minute (rpm); the one we utilize was salvaged from an old Massey Harris™ combine. Seed is removed from stems when the machine lines up the stems and seeds longitudinally, and abrades them against small plates protruding perpendicularly from the housing. As with primary combine settings, seed species differ in the optimal width of the space between the rotating bars and the fixed plates ("concave spacing"), and in the optimal rpm at which to operate the machine. Where known, these recommended specifications are provided for individual species, and these settings are assumed to be good preliminary estimates for full-scale combine harvesters as well. The seed heads and stalks left after threshing can be bundled or baled to serve as a straw mulch for weed control in seed production plots of the same species, or for erosion control on bare soils at revegetation sites.

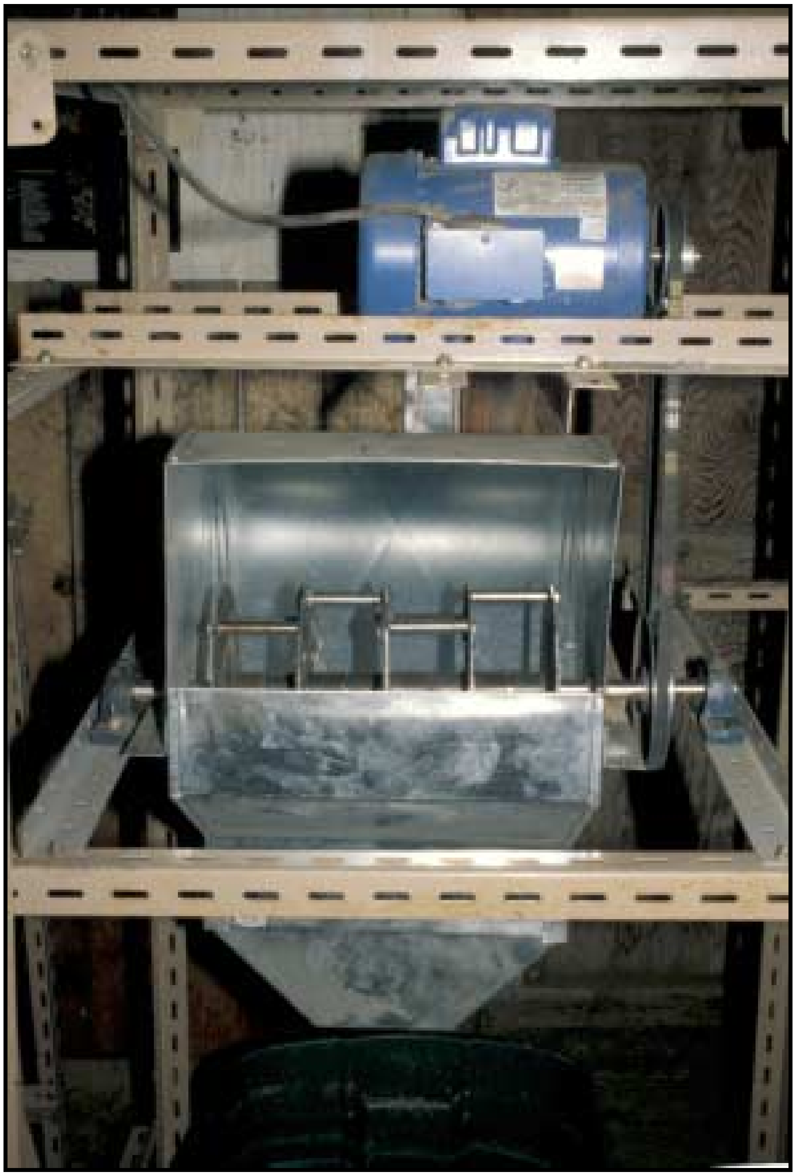

Figure 8. Custom-made rotary flail, mounted with housing and electric motor. Heads of long seed stalks are held into the unit, with the seeds knocked out of seed heads by the rotating bolts mounted horizontally between the vertical discs.

The objectives of seed cleaning are to separate pure seed from chaff and other vegetative debris, to remove the seed of any contaminating species, and (sometimes) to remove most of the small unfilled seed that is unlikely to germinate. While vegetative debris does not functionally inhibit the use of the seed in revegetation, this debris often makes seed lots more bulky and difficult to handle because the seed supply won't flow easily through machinery. Seed cleaning is generally done by one or a combination of methods: sieving by size and shape, and/or separating by buoyancy in an air stream.

We utilize a variety of brass soil sieves for manual cleaning of small quantities of seed, and for the final "finishing" step of cleaning some large seed lots. The primary cleaning operation can be done by a small fanning mill, consisting of two or more large flat shaker screens, and an adjustable stream of air generated by a large fan, all powered by an electric motor (Figure 9). As with hand sieving, screens are carefully selected by matching the size and shape of their apertures to match the upper and lower sizes of viable seeds of the crop species. Consequently, this manual reports, for each species, seed dimensions and recommended specifications for the "top screen" (which excludes seeds and debris larger than the crop seed) and for the "bottom screen" (which lets seeds and debris smaller than the crop seed fall through). Sometimes a preliminary screen is utilized too, in order to exclude larger stems, leaves, and other debris. The air stream of a fanning mill is adjusted by setting the rotation of the fan at different speeds, and/or by adjusting a baffle to damp down the wind created by the fan. Trial and error for each individual seed lot is required in order for the air stream to remove chaff and dust but not crop seed. A general guideline is that all non-crop seeds and as much debris as possible should be removed by the cleaning process, without losing more than 5% of the crop species.

Figure 9. A small fanning mill or "air-sieve machine" used for seed cleaning.

A custom-made vacuum airflow cleaner was used for some seed lots as the final cleaning step in the Symbios program (Figure 10). Many versions of such machines exist, generally connected to a commercially available vacuum cleaner that is controlled by an adjustable rheostat (a "dimmer switch"). Seed is gradually released from a hopper, and passed over an upward-flowing air stream and over one or more baffles so that heavy contaminants fall straight down, the desired seed is pushed or pulled over the first baffle, and dust and chaff continues on over a second baffle. Each machine will vary in its power, distances, baffle configuration, and the adjustments possible, so settings generally have to be made on a trial and error basis with each seed lot. As with all seed cleaning procedures, the operator has to carefully monitor that the crop is properly separated from both small and large contaminants, without losing too much of the valuable seed to the "reject" stream. The rejected material from all cleaning processes is commonly referred to as "screenings," and can be useful as a mulch for revegetation projects, so long as it is sure to be free of weed seeds.

Figure 10. A vacuum aspirator used for final separation of filled seeds from dust, chaff, and unfilled seed, based on differential buoyancy in an air stream.

Clean seed can be stored in sacks, bags, or plastic buckets and tubs (Figure 11). It is important that seed be protected from insects and rodents that might consume or contaminate it. If well cured, dry, and stored in cool dry conditions, seed from most of the species reported in this manual has proven to remain viable in storage for at least five years. Each container should be clearly labeled according to a unique seedlot identifier, denoting the species, grower or field, year of production, and any other particulars. The weight or volume of seed should be recorded, and an inventory database maintained to record additions and withdrawals of seed stocks.

In order to prepare precise seeding prescriptions, it is important to know the viability and purity of each seed lot being used. Seed lot purity simply denotes what proportion of the bulk weight consists of pure mature seeds, as determined from weight measurements of several random samples. Seed viability is usually determined from germination tests on several samples of those mature seeds, generally under standard moist warm conditions in a laboratory. These determinations can be made by the seed grower, or (more often) by specialized testing labs or seed brokerage houses. The results of seed lot tests conducted by licensed testing labs are reported in "certificates of analysis." The product of purity and viability percentages give the "pure live seed"

(PLS) content of a seed lot, important for the accurate calculation of seeding rates (see next section). Purity analysis of several samples is also important in order to check for the presence of seeds of any non-crop species. Seeds of some domesticated and weed species subsequently can be separated by recleaning the seed lot, or else the seed lot can be used for establishing agricultural pastures or hay fields. Under no circumstances should seed lots known to contain noxious weeds be used for ecosystem restoration purposes or introduced into largely wild, uncontaminated landscapes.

There is currently no requirement under the Canada Seed Act to use certified seed for purposes of revegetation or ecological restoration. There is some progress in establishing standards of germinability and purity for official certification of native plant seeds, but the many species, difficult cleaning procedures, and little trade involved means that progress in this area is slow. Once such standards are in place, hopefully they will support rather than inhibit the wider production and use of native plant seed.

Figure 11. Cleaned seed in sealed containers labeled by species, year and seedlot, and arranged alphabetically for storage in a cool dry warehouse.