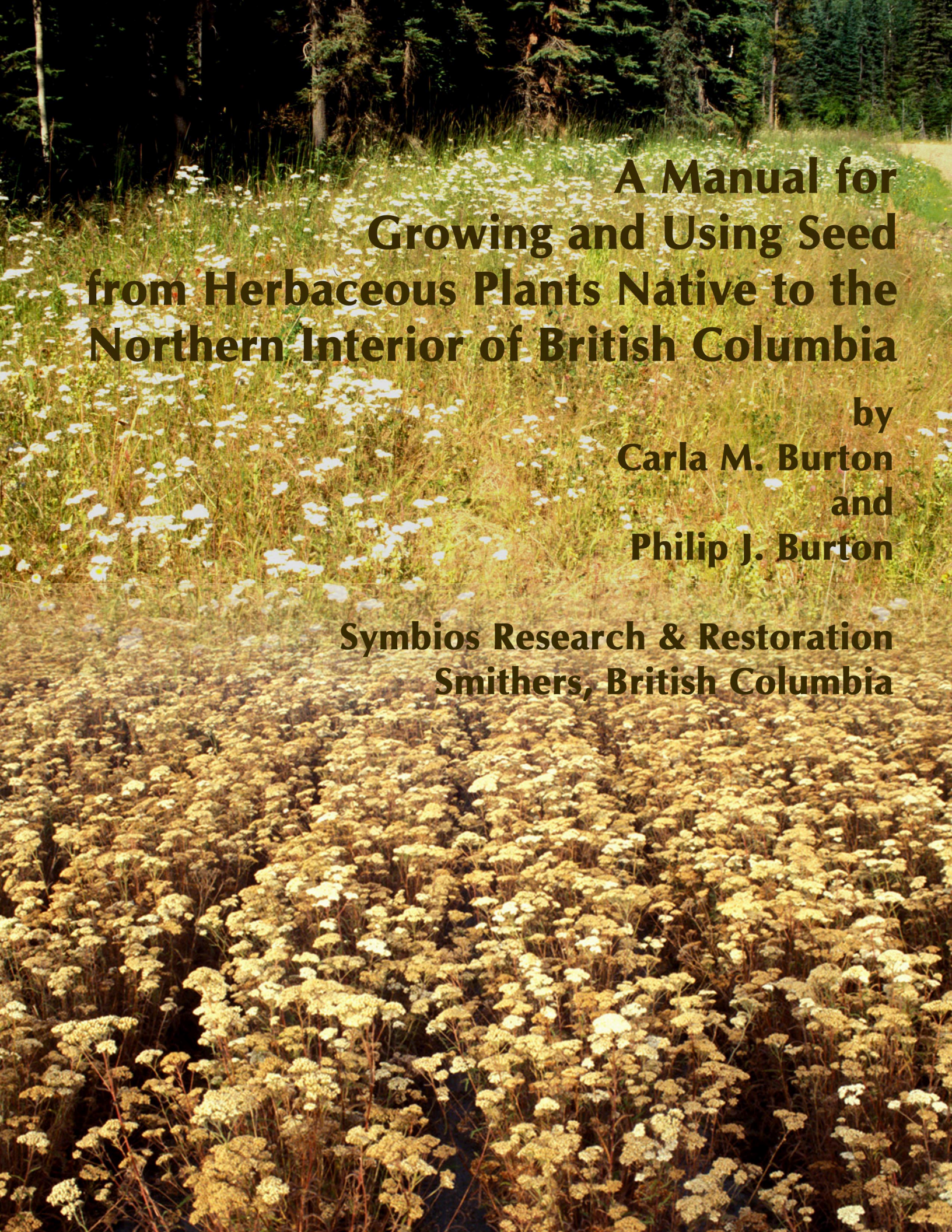

A Manual for Growing and Using Seed from Herbaceous Plants Native to the Northern Interior of British Columbia

by
Carla M. Burton
and
Philip J. Burton

Symbios Research & Restoration
Smithers, British Columbia

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This document should be considered a work in progress. Readers applying this information for growing native plants or in using native plants for revegetation are invited to relate their own results and advice to the authors. It is hoped that future editions of this manual will fill in many of the gaps in our knowledge that still exist with regard to the biology and husbandry of these plant species.

Executive Summary

It is expected that native plant materials will see increasing use for revegetating disturbed and degraded lands in northern British Columbia and elsewhere. Mixtures of grasses and legumes (and sometimes other graminoid and forb species) are sown for roadside erosion control, the rehabilitation of compacted soils, the reclamation of minespoils, and the restoration of natural grasslands. To provide reliable supplies of herbaceous native plant seed for such applications, it is advisable to grow these plants under cultivation and to harvest the seed they produce. This manual provides instructions for this process, focusing on the biology and management of 31 species of herbaceous plants indigenous to the northern Interior of British Columbia. Information is also provided to guide the process of designing seed mixtures and selecting suitable application rates for using these plants in the revegetation of disturbed soils.

Native plant seed production follows many of the standard practices of agronomy and commercial seed growing. It is recommended that production plots or fields be established on loamy soils that have been kept free of weeds for the previous one or two years, and which can be irrigated (especially during the establishment phase). Stands can be established by starting containerized seedlings in a greenhouse and transplanting them into rows, directly seeding individual or paired rows by hand or with a single-row seeder, or (especially for larger fields) using a tractor-drawn seed drill. Most native plant seeds are relatively small, so sowing depths must be shallow. Inert carriers are sometimes needed to enhance seed flow and to dilute seed concentrations when used in standard agricultural machinery. Multiple applications of fertilizer are recommended each year to offset soil deficiencies, aid in stand establishment, maximize seed production, and prolong stand life. The biggest challenge and cost to native plant seed production is always weed control, which is imperative in order to guarantee a weed-free seed supply as well as to enhance crop seed production. Weed control in seed production plots and fields can be accomplished through a combination of cultivation, mulching, manual weeding, broadcast applications of selective herbicide, or spot application of broad-spectrum herbicide. Even if all weeds cannot be killed, weed shoots or seed heads should be manually removed prior to harvesting the seed crop.

The production of native plant seed in cultivation requires careful attention to the management of genetic diversity in each species being grown. Approaches can include seed increase of single local populations, or the development of broad, regionally adapted seed supplies. In all cases, it is important to retain the variability that is associated with features such as plant stature and the timing of reproduction. This means that several selective harvests are often preferable to a single harvest of seed production stands. Harvesting methods can include: manual picking, clipping and sickles; vacuuming; motorized seed stripping; swathing followed by threshing; or straight combine harvesting. The use of plastic mulch between rows of plants can facilitate the collection of dropped or scattered seeds (providing it is free of debris and weed seeds). Seeds of several species can complete their ripening process if dried in the sun or indoors. If not threshed as part of the harvesting process or if the threshing process is not complete, a stationary threshing machine, rethresher, or rotary flail can be used to extract seeds. The straw generated from the harvesting and threshing process can be baled and used as mulch for weed control in seed production plots, or for erosion control on exposed soils at disturbed sites. This manual provides recommended harvesting and threshing methods for each species, with preliminary specifications for machine settings, but a grower must adjust these guidelines as necessary for each crop.

Seed cleaning and testing is an important component of native plant seed production. Cleaning to remove inert plant debris and non-crop seeds is typically done using a combination of sieving and controlled air-flow separation methods. Recommendations for sieve sizes and shapes, and relative air flow settings, are provided for each plant species. As with threshing, cleaning procedures will have to be adjusted for each seed lot, with the requirement that all non-crop seeds must be excluded and the general guideline that less than 5% of crop seeds should be lost in the process. Once cleaned, seed should be stored in sealed containers under cool, dry conditions. Proper seed lot identification is essential. Each seed lot then needs to be tested for its purity (apparently viable seeds as a percentage of seed lot weight) and viability (the percentage of apparently viable seeds that will germinate). For these northern species, germination should normally be tested under conditions of 25^{o}C days and 15^{o}C nights, and tests may have to extend more than 30 days.

Procedures are described for the revegetation of disturbed or degraded soils, and for the design of suitable seed mixtures to be sown on such sites. Each seeding prescription must undertake a degree of matching species to the site and to other species in a proposed mixture. Consideration should be given to the natural distribution and site preferences of candidate plant species, and to site characteristics such as elevation, slope, soil texture, management objectives, and the composition of nearby natural vegetation. Most seed mixtures will consist of tall and short grass species, a rhizomatous species, a nitrogen-fixing species, and slow and fast germinators. Species proportions and seeding rates should be based on densities of pure live seeds (PLS). A general seeding rate of 1500 PLS/m^2 is suitable for many situations, providing that a balanced fertilizer is applied at the same time. Lower rates can be used for level sites where rapid green-up is not essential, while higher rates are needed for erosion-prone sites. Seed should be applied as soon as possible after soil disturbance, or will benefit from raking, harrowing or decompaction if the soil had settled for a prolonged period of time. Seed can be spread by hand, using a cyclone seeder, or using a seed drill, followed again by raking or harrowing. Hydroseeding can also be used, but because it typically requires much more seed, it is discouraged for use with native plant seed that is often expensive and in short supply.

Most of this manual consists of information on the biology, husbandry and use of 31 herbaceous plant species, including eleven grasses, four sedges and rushes, four legumes, six composites, and six representatives of other plant families. Almost all of these species are perennials, with individual plants expected to persist in fields and in the wild for three or more years. Maps of the range of each species in northern British Columbia are provided, as are photographs of their growth habits and seeds. Information is given on growth form, site preferences, seed size, germination behaviour, techniques for seed production, harvesting and seed processing, and considerations for use in revegetation. It is expected that this information will be relevant to the growth and use of these widespread species in regions beyond northern British Columbia, and that the principles and techniques will apply to other work with native herbaceous species as well.

Though based on several years of research and experience, as supplemented by the published literature, this manual must be considered a first approximation of the knowledge needed to grow and use these plant species. Growers and revegetation specialists who work with these plants are encouraged to try different techniques, to monitor their effectiveness, and to record the results.

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Introduction

Land management in the 21st century increasingly emphasizes the need to maintain ecosystem integrity, and to restore integrity where it has been lost. Even in the recent past, it was considered responsible and sufficient to revegetate degraded sites – it didn't really matter what was grown, so long as it was green and could control erosion. Now we realize that it is possible to accomplish these goals without introducing weedy exotics or domesticated species that may out-compete native vegetation, interfere with natural succession, and alter community structure and function. It has become important to pay attention to what was growing on sites before human disturbance, so that appropriate restoration can be carried out after disturbance. Hence the increased interest in using native plants for revegetation purposes, and in growing native plants to produce the seed needed for revegetation and restoration work.

Some government agencies in both Alberta and British Columbia now require the use of native species for restoring certain disturbed sites (Gerling et al. 1996). But because native plants were not routinely used in the past, little is known about their ecology, biology, propagation and husbandry. This manual provides information on these topics. Species documented in the manual are all native to the northern Interior of British Columbia and, as such, are recommended for use in that area. However, since some of the species are found in other parts of Canada and the adjoining U.S.A., much of the specific information and general advice contained in this manual is pertinent to the broader region.

This manual takes a species by species approach to meeting two objectives: (1) providing seed growers with useful information for establishing, growing, and harvesting seed of the designated native species; and (2) providing the ultimate users of these plant materials with guidance for their use in revegetation and ecological restoration projects. We draw primarily upon our own experience in providing these recommendations, as supplemented by reference to the literature where appropriate. This manual emphasizes the husbandry and use of individual species, and is not intended to be a comprehensive manual for plant propagation or revegetation procedures in general. For good background information on native plant propagation and seed production, the reader is referred to Rose et al. (1998), Pahl and Smreciu (1999), and the propagation protocols regularly updated at the website of the Native Plant Network (based at the University of Idaho) at www.nativeplantnetwork.org. For broader overviews of relevant considerations in revegetating disturbed and degraded land, the reader is referred to Greene et al. (1992), Morgan et al. (1995), Gerling et al. (1996), B.C.'s *Soil Rehabilitation Guidebook* (Anonymous 1997), and the *Native Plant Revegetation Guidelines for Alberta* (Anonymous 2001).

Background

This manual is a product of a five year long research project conducted by Symbios Research and Restoration, based in Smithers, B.C. Funding was provided primarily by Forest Renewal B.C., to develop and test native plants for seeding in the northern B.C. Interior. Other supporters of that research included Woodmere Nursery Ltd. (Telkwa, B.C.), and the Canadian Forest Service (Pacific Forestry Centre, Victoria, B.C.). Literature reviews were first conducted to collate existing information on candidate herbaceous species. These species were identified on the basis of their widespread distribution in the region, and their frequent occurrence on disturbed sites such as compacted landings, clearcuts, skidder trails and roadsides. Over 1,000 accessions of 45 different

species were collected over three years from 22 biogeoclimatic subzones and 12 forest districts across northern B.C., from 52°N to 60°N and from the Coast Range to the Rocky Mountains. The area from which plant material was collected is broad, but seed was only collected at low to middle elevations (below alpine tree line), so these species and techniques described here are primarily applicable to the treed ecosystems of B.C.'s northern Interior. The climate is fairly homogenous in its boreal, sub-boreal, and subalpine character. Dominated by long snowy winters and short cool summers, this region approximates the zones described by the Canadian Committee on Ecological Land Classification (CCELC) as the boreal and subalpine sections of the Interior Cordilleran, Southern Cordilleran and Mid-Cordilleran ecoclimatic regions (CCELC 1989).

Some researchers and restoration practitioners advocate the use of only local plant materials when conducting ecological restoration. This approach is highly desirable and is especially important for ecological reserves, species at risk of extirpation, or for species that reproduce predominantly by selving. But such an approach ignores the potential benefits of high genetic diversity in populations exposed to a changing climate, and to the practicalities of being able to produce seed in cultivation so that it can be marketed on an economically feasible scale (for which moderately broad geographic applicability is required). Large revegetation programs, such as the roadside seeding of new logging roads and the reclamation of mine spoils, often manage dozens or hundreds of hectares of land every year, making the collection of local wild seed supplies and cuttings neither practical nor sustainable.

In the Symbios program, wild seed from diverse locations was collected in the summer and fall, dried at room temperature, manually cleaned, and stored over winter in refrigerators. Tests for germination capacity using a programmable incubator were conducted in late winter. Seed germination tests were initially conducted for 30 days at 30°C days and 20°C nights, but subsequent tests were done at 25°C days and 15°C nights, with tests often extended for many weeks until germination stopped. In early spring, all accessions were germinated in a greenhouse in peat-filled styroblocks to lengthen their first growing season and to shorten the time to seed production. Seedlings were then transplanted into outdoor seed increase plots. Each seedling was planted in a single-species plot in a computer-generated planting pattern designed to optimize the conditions for outcrossing and hence maximize the potential to produce seed with broad genetic diversity (Burton and Burton 2002). Seeds produced from these plots in the following years were also tested for germination capacity, then passed on to growers to initiate large-scale seed production. Over the course of the project, several species were eliminated due to poor germination, or harvesting and cleaning difficulties.

Field trials testing various species combinations, sowing densities, mulches, and the use of fertilizer were conducted over the course of four growing seasons, and were monitored for 2 or 3 years after seeding. Details of these and other tests and procedures in the development of native seed supplies are provided in the final report for the project (Burton and Burton 2001a), which is available from the authors. Information for the 31 species included in this manual was obtained from direct experience in cultivation and revegetation trials, supplemented by information from the literature and other researchers. These species are presented with their plant family affiliation in Table 1. Most of this manual consists of species by species accounts of growth form, site preferences, seed size, germination behaviour, techniques for seed production, harvesting and seed processing, and considerations for use in revegetation. Some general guidelines apply to all species, as presented in the next section, but much of this information is repeated in the individual species treatments so that those subsections can stand alone as well.

Table 1. The plant species covered in this manual, organized by plant family.

Family	**Species**	**Family**	**Species**
Asteraceae	*Achillea millefolium*	Polemoniaceae	*Polemonium pulcherrimum*
	Anaphalis margaritacea	Poaceae	*Agrostis exarata*
	Arnica chamissonis		*Bromus ciliatus*
	Arnica cordifolia		*Calamagrostis canadensis*
	Aster conspicuus		*Calamagrostis rubescens*
	Aster foliaceous		*Elymus glaucus*
Cyperaceae	*Carex aenea*		*Elymus trachycaulus*
	Carex macloviana		*Festuca occidentalis*
	Carex mertensii		*Leymus innovatus*
Fabaceae	*Lathyrus ochroleucus*		*Poa alpina*
	Lupinus arcticus		*Trisetum spicatum*
	Lupinus polyphyllus	Rosaceae	*Dryas drummondii*
	Vicia americana		*Geum macrophyllum*
Juncaceae	*Luzula parviflora*		*Festuca saximontana*
Liliaceae	*Allium cernuum*	Scrophulariaceae	*Collinsia parviflora*
Onagraceae	*Epilobium latifolium*		

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).

Site Selection and Preparation

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.

5More 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.

General Considerations for Use in Revegetation

Regionally adapted native plant seed is likely to remain a valuable commodity in northern British Columbia for the foreseeable future, whether collected from the wild or grown in cultivation. Consequently, every effort must be made to optimize its use and to maximize its effectiveness for revegetation and restoration. While revegetation procedures will vary with local site conditions and project goals, some generalizations can be made. Foremost among these general rules are to:

introduce seed to freshly loosened soil;
match the species selected to local soil and site conditions;
avoid or minimize the effects of weeds;
remember that stand establishment will often take two growing seasons; and
employ an adaptive management approach (testing different techniques and monitoring their effectiveness on an operational basis).

Site Preparation

It is important to prepare a receptive seedbed that will have good mineral soil exposure, good soil-seed contact, and will support unimpeded root growth. Many sites degraded by industrial activities such as road building, log loading, or overgrazing have very compacted soil. This first must be alleviated by deep cultivation, disking, or ripping. The rooting zone should be loosened (cultivated) to 10 or 15 cm if possible, and heavily compacted sites (such as former roads and landings) may need to be ripped or treated with a winged subsoiler to depths of 40 cm (Bulmer 1998). Simple raking or harrowing of the surface is insufficient to provide an optimal growing medium in most cases, but is better than no treatment at all. The removal or rearrangement of logs, brush, and stones is not necessary or desirable on most revegetation sites, as these features contribute to microsite diversity.

If the remnants of the pre-existing native plant community are already found on the site, one may not want to disrupt the vegetation, no matter how depauperate or degraded it might be. The existing vegetation can be directly "over-seeded," but provisions for inserting the seed into or onto the soil must be considered, and some degree of site preparation is still desirable. This may consist of mowing the existing vegetation to a short stubble, or raking/harrowing the soil surface to expose some bare soil. Manual removal of weeds or spot-spraying of weeds and other exotic plants with a broad-spectrum herbicide may be desirable. If the weeds are annuals, mowing or clipping them at the time of flowering (i.e., before they go to seed) can help shorten their hold on the site. When digging up perennial weeds such as bull thistle (*Cirsium vulgare*), the filled-in shovel holes left behind then consist of loose, bare soil that is well suited for immediate seeding with native plants.

When tillage or harrowing is conducted on sloping terrain, it is essential that furrows run parallel to the contours (perpendicular to the direction of slope) in order to minimize erosion. Very steep road cuts are difficult to revegetate unless they are terraced or re-sloped to the natural angle of repose for loose, unconsolidated material. A more common solution, employed for both agronomic and native species, is to use hydroseeding techniques in which commercial "tackifiers" can be added to a slurry of water, seed, fertilizer and mulch that is then applied to the site using a specialized pump and nozzle. The tackifier essentially glues the seed to steep slopes, so some seed will be in place to germinate and establish if weather conditions cooperate.

Optimal conditions for seeding disturbed lands exist immediately after soil disturbance or site preparation. If disturbed soil is left too long, weeds will have a chance to invade and establish. Weathering results in soil settling over time, and silt and clay particles will fill most soil cracks, resulting in a gradual recompaction of the soil.

Soil Amendments and Mulches

Sites degraded by industrial activities often consist of compacted soils, stripped of topsoil and plant nutrients. Consequently, some degree of soil improvement is often needed in order to support more than sparse plant growth, and to restore healthy ecosystem functioning. When the area to be revegetated is dominated by subsoil, bare parent material, or shattered lithic material, one challenge is to accelerate soil development. In addition to decompacting this material (as described above), it can also be useful to incorporate organic matter into the substrate to improve soil structure and to provide cation-exchange sites for the retention of nutrients and soil water (Bulmer 1998). Suitable amendments can include wood chips, sawdust, peat moss, straw, manure, or various waste treatment sludges (e.g., from pulp mills, fish farms, or municipal sewage treatment plants). Care must be taken to manage the carbon to nitrogen (C to N) ratio of these amendments. If material with a high cellulose content (e.g., wood chips, sawdust, or straw) is added to the soil, it will be decomposed by soil fungi and bacteria, but those fungi and bacteria will gobble up most of the available nitrogen in the soil, thereby depriving plants of adequate resources for growth. So any time amendments with high C:N ratios are used, supplemental fertilization with nitrogen-rich or low C:N materials must also be done. This fertilizer can be from commercial sources (e.g., ammonium nitrate formulations), or from organic sources (such as manures, or municipal sewage).

Soil amendments should be well incorporated into the rooting zone of the substrate, typically the top 10 to 20 cm, before seeding. This will usually require the use of farm machinery such as a disker, plow or cultivator, as part of site preparation procedures. If applied as a surface dressing or mulch, amendments are not as effective for soil improvement, but can be important for erosion control, especially on sloping sites. Surface mulches are generally applied after seeding, rather than before. Mulch should not be applied too thickly (generally less than 1-2 cm) or densely, (<70% cover), so that seedling emergence is not inhibited. Suitable mulches for revegetation and restoration activities include straw from annual cereal crops (i.e., wheat, oats, barley, rye), or the straw and screenings from native plant seed production fields. Care must be taken not to introduce weed seeds or other contaminants with the mulch. For example, hay bales from fields of domesticated smooth brome (*Bromus inermis*), timothy (*Phleum pratense*) and clover (*Trifolium* sp.) might contain viable seeds of those exotic agronomic species. So use of hay mulch is not recommended, as the exotic seeds might defeat the purpose and expense of introducing native plants in the seeding process.

Fertilizer is often applied when sowing a revegetation site, even if organic matter is not incorporated into the soil. This is because most degraded sites are nutritionally barren, with substrates often consisting of unmodified glacial till. Furthermore, the enhanced plant growth achieved through the use of fertilizer can stretch sparse supplies of native seed by generating more plant cover per plant and greater probability of seedling survival (Burton and Burton 2001a). Where no intact topsoil remains, a balanced, high-concentration fertilizer (e.g., 18-18-18 or 13-16-10 NPK) applied at a rate of 200 to 300 kg/ha is generally sufficient to promote vigorous plant growth. Supplemental fertilization may be beneficial in another three years or so, depending on the chemistry of the site, the effectiveness of plant establishment and the initiation of nutrient cycling

above and below ground, and on the success of nitrogen-fixing species. Natural fertilizers such as manure, fish farm waste, or municipal sludge can be beneficial substitutes, since they also include organic matter. If possible, soil testing should be conducted to document the precise nutrient limitations, so that fertilizer prescriptions can be optimized. The heterogeneity of soil conditions on many revegetation and restoration sites often precludes accurate diagnostic soil testing. It is safe to generalize, however, that N will usually be more limiting than P, K, or other nutrients on degraded soils in northern B.C. Contrary to some recommendations, our research has shown that fertilization even benefits native plant establishment on sites dominated by agricultural weeds (Burton 2003).

The Seeding Prescription

Designing the mixture of species and the density at which they should be applied to a site constitute the fundamental elements of a revegetation prescription. To optimize the use of scarce seed, it is strongly recommended that sites be roughly mapped and categorized according to soil texture, topographic position, and/or vegetation goals, so that customized seed mixtures can be assigned to each site class. Gravelly soils in low-lying sites should receive a different mixture of species than gravelly sites on upper slopes and ridge crests, while fine-textured or loamy soils require yet a different suite of species. Site preferences and tolerances, where known, are provided below in the individual species accounts.

In formulating a seed mix, it is useful to employ a combination of 5 to 10 species, consisting of some graminoids (grasses, sedges, and rushes) of low and high stature, some species with rhizomes, some (usually legumes) with nitrogen-fixing ability, and some fast germinators. Care should be taken to ensure that the mix will not be dominated by a single aggressive species, and the mature stature of each species should be considered when deriving the ratio of seeds to use. That is, only a few individuals of large-statured species (e.g., *Lupinus polyphyllus*) are needed, while many individuals of smaller plants (e.g., *Festuca occidentalis*) are required to achieve the same proportional crown cover per unit area. Other considerations, such as the decision to include or exclude species highly palatable to livestock or wildlife, or the decision to include species resistant to trampling, will enter into the design of a mixture according to the land use goals for the land being revegetated. The soil texture, site drainage, and soil fertility of the site to be revegetated must also be considered and matched to the most suitable species. For example, many of the species covered in this manual can establish and grow well on gravelly soils, but *Dryas drummondii* and *Epilobium latifolium* are more demanding of coarse soils than other species, but still need good access to soil water, so are usually limited to lower slope positions. *Geum macrophyllum*, in contrast, is most suited to loamy soils with high nutrient levels.

It is worth considering the inclusion of a fast-germinating and fast-growing "cover crop" on steep bare sites where heavy precipitation or spring runoff is expected to generate a risk of soil erosion. Most native plants (with some exceptions) are relatively slow to establish and achieve full stature, so some non-native species would need to be used. The challenge is to find species that will quickly generate cover, but will not persist and compete with the native plants as they establish and grow. Suitable cover crops include fall rye (*Secale cereale*), Italian ryegrass (*Lolium multiflorum*), and sterile hybrids of slender wheatgrass and wheat (*Elymus trachycaulus* x *Triticum aestivum*, sometimes marketed under the trade name of Regreen™). When added to a native plant seed mixture, such cover crops should be added on top of the desired native plant seeding rate, and should not constitute more than 10 to 20% of the total seed mixture applied to the site.

All seeding ratios and densities should be formulated on the basis of the amount of pure live seed (PLS) per unit area, not the weight of seed or seed stocks. This is because plant species vary greatly in seed size and consequently in the number of seeds per kg, and individual seed lots also tend to vary in the number of viable seeds per unit weight (relative to other contaminants like dust and plant debris). Adjustments for PLS are required in order to refine the amount of seed to be weighed out and applied to a site. For example, if your seedlot is 90% pure mature seed (by weight), and those seeds exhibit 90% viability, then every 25 kg bag of seed only contains 0.9 x 0.9 x 25 = 20.25 kg or pure live seed. Combined with knowledge of the number of seeds per gram for a particular seedlot or species (as provided for each species below), this determination allows the inter-conversion of seeding densities in PLS/m^2 and in kg/ha. Prescriptions should be developed in PLS/m^2, but those prescriptions are usually implemented in the field in terms of kg/ha. Individual species treatments (below) include the mean and range of the number of seeds per gram, and the mean and range in germination capacity encountered in the Symbios research program; seed lot purity varies with every crop and every seed cleaning operation, however. Table 2 provides a sample worksheet for the preparation of a seeding prescription. Such a table can be easily transcribed to a computer spreadsheet program, in which the amount of seed of each species to be weighed out and the total application rate can then be calculated.

Table 2. Sample worksheet and worked example for preparing a seeding prescription and calculating the amount of seed (of each species) to be mixed and sown over a given area.

Area to seed: 12,000 m^2 Plant Species	Plant Material Origins		Seeds per gram	Seedlot		Application Rate		Notes
	Location Or Vendor	Year or Seedlot		Purity, % of wt.	Viability, % germ.	desired PLS/m^2	Total g or kg	
A.	B.	B.	C.	D.	D.	E.	F.	G.
1. *Elymus glaucus*	Symbios	ET2001	228	93	80	300	2112g	
2. *Festuca occidentalis*	Symbios	WM2001	2995	84	91	650	3407g	
3. *Achillea millefolium*	Symbios	CFS2000	7560	71	90	500	1242g	
4. *Lupinus polyphyllus*	wild:P.G.	2000	117	95	77	50	7010g	add Rhizobium B
5.								
6.								
7.								
8.								
9.								
10.								
H. TOTAL:						1500	13771g	=11.48 kg/ha

Instructions: A. Select species based on site attributes, management objectives, and seed availability.

B. Record plant material origins, making sure they are suitable for your location.

C. Insert seeds per gram from published averages (e.g., means reported as part of individual species treatments, below), or based on seedlot analysis.

D. Insert seedlot purity and viability on the basis of seedlot tests or certificates of analysis.

E. Specify the desired PLS/m^2, based on the stature and aggressiveness of each species, speed of germination, site attributes, and desired plant community structure, so that all individual species sum to the total PLS/m^2 desired.

F. Calculate the total number of grams of seedlot needed for each species as:

= area to seed (in m^2) x desired PLS/m^2 / (seeds/g x % purity x % viability);

record % purity and % viability as proportions (0 to 1) for use in this calculation; divide result by 1,000 to express large values in kg, if desired.

G. Record additional information as needed, such as price, checking off each species as weighed, etc.

H. sum individual species application rates to derive total seed mix application; divide total application rate in g by area to seed (in m^2) and multiple by 10 to give application rate in kg/ha, or divide total application rate in kg by area to seed in m^2 and multiply by 10,000 to give application rate in kg/ha.

The amount of PLS applied to a site will not result in an equivalent density of plants. Though all PLS should theoretically germinate, our experience indicates that only 10% to 20% of those seeds will successfully germinate, emerge, and establish as seedlings on degraded sites. This low success rate is due to a variety of suboptimal practices (e.g., surface sowing instead of drill seeding), harsh site conditions (e.g., infertile or compacted soil), and accidents of weather and herbivory (e.g., frost, drought, grazing by insects or small mammals). Recent research with plants native to northern B.C. indicates that adequate amounts of cover can be achieved across a broad range of sowing densities (375 to 6000 PLS/m^2), but full cover is attained faster at densities ranging from 750 to 1500 PLS/m^2 (Burton 2003). A broadly applicable and generally acceptable recommendation is for 1500 PLS/m^2 when broadcast-sown as a dry seed mix, with higher rates recommended on erosion-prone sites, where rapid green-up is desired, or where weeds populations are high. Lower densities are acceptable if seed is in short supply, if weeds are not a threat, and if establishing cover quickly is not a priority.

Sowing and Monitoring

Seed can be introduced to a site by drilling it into the soil using standard or modified agricultural machinery, broadcast using cyclone spreaders (mounted on a helicopter sling, on the back of a tractor, an ATV, or operated by hand), spread directly by hand, or as part of a slurry by hydroseeder. Drill seeding is most efficient in terms of ensuring that a large proportion of the seeds will have good contact with the soil and will successfully germinate and emerge; unfortunately, it is not suitable for rough or steep terrain, and is not currently the norm for most roadside seeding. Next efficient is dry broadcast seeding (Figure 12), so long as it is conducted quickly after soil disturbance or after soil loosening by raking or harrowing, and then is followed up by more raking or harrowing. Small areas can be sown by hand if care is taken to distribute seed evenly. Hydroseeding is least efficient in terms of the use of seed, but the presence of tackifier (an organic soil binder) can greatly enhance its effectiveness on steep slopes. Typically mounted on the back of a large truck along with a big mixing tank, hydroseeders can also be small enough to fit on a pickup truck. Simple substitutes can be built using some water pumps, so long as the pumping mechanism does not damage seeds and nozzle apertures are big enough for the seeds being applied. Hydroseeding is not currently recommended for most native plant seed application purposes (except for steep sites), because it uses approximately three times the amount of seed that is used in dry broadcast seeding applications. A large amount of hydroseeded seed ends up being applied to unsuitable microsites and obstacles, and much of the seed is found in the upper layers of the mulch where it dries out, rather than under the mulch where it is protected. So a recommendation of 1500 PLS/m^2 for dry seeding should be adjusted to 4500 PLS/m^2 when hydroseeding is used.

Domesticated legumes are routinely treated with bacterial inoculum before being sown. This may not be necessary for native legumes, for which natural inoculum seems to be widespread in the forest environment. However, for very sterile and isolated locations such as large mines, it may be prudent to coat legume seeds with commercial inoculum before sowing. Different strains of *Rhizobium* are needed for each legume genus, with each vendor using different names or labels for the strains applicable to *Lathyrus*, *Lupinus*, or *Vicia*. Inoculum can be mixed in a powdered milk slurry so it lightly coats the legume seeds before they are added to the seed mix.

Figure 12. Dry broadcast seeding along a newly built logging road, spreading a grass-legume seed mix using a cyclone seeder mounted on an all-terrain vehicle (ATV).

It is generally recommended that one weigh out and mix the different species in a seed mixture ahead of time (i.e., in the warehouse). When dry seeding, fertilizer and mulch (if used) are generally applied to the site in separate steps from the seed. It helps to weigh out bags or tubs of seed for each discrete stratum (e.g., moist sites, ridge crests, gravel patches, etc.) or fixed areas of uniform land (e.g., in 100 m^2, 900 m^2, or 2500 m^2 units). Then flag out the boundaries or corners of each unit of land on the revegetation site, so that the rate of seeding can be adjusted to make sure it uniformly covers the designated area. Until experience is acquired at judging the rate of application, it is better to seed sparsely at first and then do a supplemental application, rather than to run short of seed because original application rates were too generous. The site should be raked or harrowed to expose fresh, loose soil immediately before seeding (as mentioned above), and then raked, harrowed or dragged to cover the seeds somewhat after sowing too (Figure 13). In northern B.C., seeding can be done in the spring (any time before July) or in late summer, but late fall seeding is often best.

Figure 13. Raking or harrowing after broadcast seeding is recommended to promote seed germination and seedling establishment.

All revegetation and restoration prescriptions and subsequent seeding operations using native species should be considered experimental in nature. That is, they may represent your best effort at designing an appropriate mixture and density of seeds and associated amendments, but there is no *a priori* reason to expect this design to be the optimal solution to local site management challenges. It is therefore prudent to incorporate assorted modifications to the restoration prescription, apply them at multiple locations, keep careful records of what treatment was employed where and when, and to monitor the results. Monitoring might be as simple as the installation of permanent photo points, with photographs taken of each treatment area at the same time of year over a number of years. Or it might be as quantitative as a rigorous program utilizing line transects or randomly located quadrats to sample plant cover and density (Figure 14). A template for recording plant density and cover observations in three quadrats per treatment stratum is provided in Table 2. Note that it is usually worthwhile to record weed cover and evidence of soil erosion and the accumulation of organic matter as well as the abundance of each plant species. A more rapid form of monitoring can consist of recording plant cover in four broad groups: sown species, other native plants, agronomic grasses and legumes, and weeds. Whatever the nature and intensity of monitoring undertaken, it is important to adopt a philosophy of structured adaptive management, constantly improving one's expertise in restoring native vegetation.

Figure 14. Sampling the density and cover of native plants sown on an old log sort yard.

Revegetation success ultimately depends on the establishment of an adequate amount and composition of plant cover. Depending on the goals of the project, the vegetation may be expected to be a faithful re-creation of a natural plant community, and to dominate the site indefinitely. In other situations, it will be sufficient for the vegetation to reduce erosion, and to cover the soil for only a few years until tree and shrub species dominate the site. Mowing or weeding of exotic plants may be desired in some cases, and supplemental fertilization in two or three years may be appropriate, depending on the land use goals. But areas revegetated to native plants are generally expected to be self-maintaining.

The value of creating a plant assemblage that is pleasing to the eye (Figure 15) should not be underestimated, as public support for the wider use of native plants still needs to be nurtured. Coupled with a desire to promote biodiversity and to mimic the composition of natural meadows, such aesthetic considerations provide another incentive for including non-leguminous wildflowers in native plant seed mixtures.

Table 3. Sample data collection form for monitoring plant community development after revegetation. This form records plant count and cover observations from three quadrats (remember to record quadrat area, e.g., 0.25 m^2 or 1.0 m^2); x and y values denote random rectangular coordinates for each sample.

Location:_____ Monitored by:_____ Date: _____

Stratum/Treatment:_____

	Sample 1		Sample 2		Sample 3	
Species or attribute	x=_____m	y=_____m	x=_____m	y=_____m	x=_____m	y=_____m
Seeded species	density	Cover	density	cover	density	Cover
Achillea millefolium						
Carex aenea						
Elymus glaucus						
Festuca occidentalis						
Geum macrophylum						
Lupinus polyphyllus						
Native invaders						
Agrostis scabra						
Aster sp.						
Betula papyifera						
Calamagrostis canadensis						
Collinsia parviflora						
Epilobium angustifolium						
Epilobium ciliatum						
Equisetum arvense						
Hieracium albiflorum						
Picea glauca x engelmanii						
Populus trichocarpa						
Rosa acicularis						
Salix sp.						
Exotic Agronomics						
Agrostis stolonifera						
Dactylis glomerata						
Festuca rubra						
Phleum pratense						
Poa pratensis						
Trifolium sp.						
Exotic Weeds						
Agropyron repens						
Cerastium fontanum						
Chrysanthemum leucocephalum						
Cirsium vulgare						
Galeopsis tetrahit						
Sonchus arvensis						
Taraxacum officinale						
Ground Cover / Physical features						
moss						
stones/wood						
erosional rills						
litter (leaves, etc)						

Figure 15. A successfully established stand dominated by *Elymus glaucus*, *Festuca occidentalis*, and *Achillea millefolium*, with scattered *Bromus ciliatus*, *Lupinus arcticus*, *Geum* macrophyllum, *Carex* species and *Aster* species. This mixture was sown along recent ski trail improvements and along a forest access road in the Smithers Community Forest, with seeding done by volunteers from the local cross-country ski club. This photograph was taken two growing season after sowing.

Some Examples of Native Plant Seeding Prescriptions

As indicated above, it is desirable to devise a seed mixture and seeding rate to match the site conditions and objectives of every revegetation project undertaken. We here provide some examples of species mixtures designed to meet certain revegetation goals and site conditions, not to serve as a fixed set of "off the shelf" mixtures, so much as examples of the decision process by which species and seeding densities are chosen.

The first example describes a **general-purpose mixture** for seeding newly constructed roadsides and ditches where the glacial till substrate consists of bare, gravelly clay loam:

Festuca saximontana	23%
Festuca occidentalis	26%
Elymus glaucus	18%
Achillea millefolium	25%
Lupinus arcticus	8%

Because erosion control and rapid cover production are priorities, the recommended application rate for this scenario is fairly high, approximately 2500 PLS/m^2. A short-lived, fast-growing cover crop of fall rye, Italian ryegrass, or Regreen^{TM} could be added at rates of approximately 200 PLS/m^2. This mixture is dominated by three grass species: a tall one of medium longevity (*Elymus glaucus*);

a long-lived one of medium stature (*Festuca saximontana*); and a short-lived one with very rapid germination and short stature (*Festuca occidentalis*). The grasses are supplemented by a large amount of *Achillea millefolium*, which germinates rapidly, generates rosettes of low-lying foliage, and is rhizomatous, so provides valuable erosion control. Note that more *Festuca occidentalis* and *Achillea millefolium* seeds per m^2 are prescribed than *Elymus glaucus* and *Lupinus arcticus* seeds, because the latter two species are much larger when mature. *Lupinus arcticus* is included as a native nitrogen-fixer, but 300 kg/ha of 19-18-18 fertilizer is recommended for spreading at the time of seeding as well. Other native legumes, such as *Vicia americana*, could substitute for *Lupinus arcticus*, depending on seed availability and site conditions: if soils are "heavy" or clayey rather than gravelly, sandy or loamy, *Lupinus polyphyllus* would be a better choice. A variety of composites or other "wildflower" species could be added to the mixture to add a little colour and diversity, but these species should not constitute more than 10-15% of the total mix.

A second example describes a seed mixture recommended for a **lower slope position** that is either moisture-receiving, adjacent to a wetland or riparian area, or is characterized by seepage. Such sites might require revegetation in support of riparian restoration plantings of cottonwoods and willows, or they might be on the fringe of a reservoir subject to variable water levels, or in roadside ditches that tend to remain moist. Suggested species and proportions are:

Calamagrostis canadensis	23%
Carex mertensii	15%
Carex macloviana	12%
Collinsia parviflora	12%
Elymus glaucus	10%
Achillea millefolium	7%
Bromus ciliatus	6%
Geum macrophyllum	5%
Dryas drummondii	5%
Arnica chamissonis	3%
Lupinus polyphyllus	2%

This mixture of 10 species includes a variety of moisture-loving species and some that are more tolerant of upland conditions. *Calamagrostis canadensis*, *Carex mertensii*, *Elymus glaucus*, and *Geum macrophyllum* are naturally abundant on moist sites, though all can tolerate upland conditions to a degree. *Carex macloviana* and *Bromus ciliatus* are included as short-statured and tall-statured upland graminoids, respectively. *Arnica chamissonis* and *Geum macrophyllum* are both known to prefer rich sites, and should provide good cover and contribute to vegetation diversity. *Achillea* is once again included as a fast germinator, and *Lupinus polyphyllus* as a nitrogen-fixer. *Dryas drummondii* should be included only if the substrate is sandy or gravelly, with water flowing through the site but not standing. It was recommended that this prescription could be sown at 1200 PLS/m^2, or at higher application rates on slopes of bare soil where erosion is a concern. Fertilizer is again recommended, though the rate of application does not need to be high (perhaps 150 to 200 kg/ha of 18-18-18) if some topsoil or subsoil is found on the site.

A third example describes the sort of seed mixture designed for a **high-elevation or high-latitude area** (such as the Engelmann Spruce – Subalpine Fir or Spruce-Willow-Birch biogeoclimatic zones) with rocky soils and a short growing season. Such a site might need to be reclaimed after mining or mineral exploration, or might consist of the sides of a new road, or disturbances associated with the expansion of a ski resort. A recommended mixture for this scenario is:

Festuca saximontana	25%
Trisetum spicatum	18%
Poa alpina	18%
Achillea millefolium	14%
Luzula parviflora	10%
Epilobium latifolium	10%
Lupinus arcticus	5%

The backbone of this mixture consists of two medium-statured grasses, *Festuca saximontana* and *Trisetum spicatum*, supplemented by the shorter *Poa alpina*, all well-adapted northern, alpine and subalpine species. *Achillea millefolim* is again included for rapid germination and cover production, especially on steep sites where rapid erosion control is desired. *Luzula parviflora* is a graminoid that may provide low-lying ground cover too. *Lupinus arcticus* is included as a nitrogen-fixing legume, while *Epilobium latifolium* is a natural invader and useful cover-producer on well-drained (rocky) sites so long as moisture is available below the surface. Seeding of such sites is often best in fall, so that seeds will be in place well before access can be regained to such places in the spring. Light fertilization would be beneficial (50 to 150 kg/ha of 18-18-18), for such sites are nutrient-poor but plant growth tends to be more temperature-limited than nutrient-limited.

A final example describes the restoration of spot disturbances in a new nature reserve that includes a **sloping grassland** in the dry cool subzone of the Sub-Boreal Spruce biogeoclimatic zone (SBSdk) in the Bulkley Valley. These threatened ecosystems are classified as "Site Series 81, Saskatoon – Slender Wheatgrass Scrub/Steppe" (Banner et al. 1993). The natural vegetation of the site is largely intact around the disturbed areas, and is dominated by slender wheatgrass (*Elymus trachycaulus*) and Rocky Mountain juniper (*Juniperus scopularum*). Because this is a nature reserve, and the goal is **ecosystem restoration** (not just revegetation), priority is placed on the use of species documented to already occur in the project area; locally collected seed is used as much as possible. Soils are largely intact, fairly rich in level spots (which also had weed problems), but are shallow and dry on sloping areas. Existing plant cover makes erosion control a lower priority. Rather than digging up or herbiciding the exotic plants (especially *Chenopodium album* and *Cirsium arvense*) found on the site, these are manually cut or mulched with plastic ahead of time, and are then overseeded. The soil is manually raked before and after sowing. No fertilizer is used on the weedy areas; elsewhere, a light sprinkling of 13-10-10 fertilizer is applied at approximately 150 kg/ha. A light mulch consisting mostly of native *Elymus glaucus* straw and screenings is spread on areas with bare soil in order to partially shade new seedlings and help conserve moisture. The seed mixture and proportions (of PLS) devised for this project are as follows:

Elymus trachycaulus	45%
Achillea millefolium	18%
Collinsia parviflora	13%
Bromus ciliatus	7%
Elymus glaucus	7%
Anaphalis margaritacea	4%
Aster conspicuus	2%
Polemonium pulcherrimum	2%
Vicia americana	2%

This mixture is to be applied at 1550 PLS/m^2 in early spring, soon after snow is gone from the site. All eight species are naturally found in the nature reserve. To restore the grassland, heavy emphasis is placed on introducing the dominant *Elymus trachycaulus*, with lesser amounts of *Bromus ciliatus*

and *Elymus glaucus*, so that grasses (all tall in stature) should constitute 59% of the seedlings. Though few short-statured or rhizomatous native grasses are found in the local vegetation (at least none for which seed was available), *Achillea millefolium* was found on site. So *Achillea* is included at a fairly high density in order to provide a fast-germinating and low-lying ground cover. *Collinsia parviflora* is a native annual and may also provide rapid cover if germination conditions are favourable, but it can also persist in the seed bank and may be a useful contributor to the native plant community in the future. *Vicia americana* is included as a native nitrogen-fixer, and more would have been used if seed supplies had been available. The other three species in the mixture (*Anaphalis margaritacea*, *Aster conspicuus*, and *Polemonium pulcherrimum*) can be considered enriching elements of biodiversity, wildflower species found on the site which may be important for certain insects, for aesthetics, and to contribute diversity and resilience to the vegetation.

Individual Species Treatments

The rest of this manual consists of descriptive information on each of the 31 species for which we gathered information, based on published sources and our own research and experience. Each species description includes a range map for northern B.C., photographs of the plant's habit and seeds, general background information, description of the growth form, site preferences, seed information, techniques for seed production, harvesting and seed processing information, considerations for use in revegetation, and other general comments on the properties or husbandry of the species. If not otherwise cited, information has been derived from the Symbios Research & Restoration research program, some results of which have been previously summarized in Burton and Burton (2001b). Reference is also made to a number of other sources and researchers, particularly from Alberta where valuable research on the use of native grasses has been carried out over the last two decades. General comments from growers and practitioners are used when no quantitative information is available on a particular species. When noted, information from related species has been extrapolated to similar species presented in this manual.

A map of its geographical distribution in northern British Columbia is provided for each species. Each map is first and foremost a "dot map" at a scale of 1:7,000,000, documenting the location of verifiable plant collections or sightings. Three primary sources of information are portrayed, each by a different symbol (as shown in the map keys):

Herbarium collections, as accessioned at the National Museum of Nature (Aylmer, Quebec), Agriculture and Agri-foods Canada (Ottawa, Ontario), the Royal British Columbia Museum (Victoria, B.C.), the University of Victoria (Victoria, B.C.), the University of British Columbia (Vancouver, B.C.), the University of Northern British Columbia (formerly the herbarium of the Prince George Forest Region, in Prince George, B.C.), and the Prince Rupert Forest Region (B.C. Forest Service, Smithers, B.C.);

Relevé data from the master database of more than 7000 sample plots collected over more than 20 years throughout the province in support of the biogeoclimatic ecological classification (BEC) program; this was made available to the authors by the B.C. Ministry of Forests; and

1076 accessions of seed collected by Symbios Research and Restoration in support of the five-year research program described in Burton and Burton (2001b).

The biogeoclimatic subzone in which a species was observed has been shaded yellow, and represents an extrapolation of the likely range of the species. It should be noted, however, that the central Interior of northern British Columbia has been only sparsely botanized, especially away from main roads. So it is likely that sub-zones similar and adjacent to those shaded in each map also support the species in question. The subzones represented by Symbios seed lines is further highlighted with green shading.

There is a considerable reference list associated with this manual because an effort was made to gather as much information as possible about each species. Some of the information is old (dating back to the 1930's) and second-hand (as denoted by an asterisk and footnote), but it was considered important to provide the reader with access to all primary sources. We downloaded much valuable information from the Fire Effects Information System (available at www.fs.fed.us/database/feis/plants; FEIS various dates), maintained by the U.S. Forest Service; many of the obscure references were derived from this database. Most species descriptions were derived from the *Illustrated Flora of British Columbia* (in seven volumes, by Douglas et al. 1998-2001). Growth form and site preferences were gleaned from a variety of sources but *Plants of Northern British Columbia* by MacKinnon et al. (1992) was particularly useful in this regard.

Standard biogeoclimatic acronyms, as utilized for ecological site classification and land management across B.C., are employed in the text. The biogeoclimatic zones found north of the 52nd parallel in B.C. are:

AT = Alpine Tundra;
BWBS = Boreal White and Black Spruce;
CWH = Coastal Western Hemlock;
ESSF = Engelmann Spruce - Subalpine Fir;
ICH = Interior Cedar-Hemlock;
MH = Mountain Hemlock;
SBPS = Sub-Boreal Pine and Spruce;
SBS = Sub-Boreal Spruce; and
SWB = Spruce-Willow-Birch.

Interior subzone designations use the following notation, referring to the precipitation regime and temperature regime relative to other subzones within the same biogeoclimatic zone:

First letter, x = very dry, d = dry, m = moist, w = wet, v = very wet;
Second letter, h=hot, w = warm, m=mild, k = cool, c = cold, v = very cold.

So "the SBSdk," for example, refers to the dry cool subzone of the Sub-Boreal Spruce zone. For background and details of the British Columbia BEC system, and environmental and ecological descriptions of the BEC zones and subzones, readers are referred to Meidinger and Pojar (1991).

Site or ecosystem affinities of individual species can also be identified in some cases. Here we follow BEC ecosystem classification protocols (Meidinger and Pojar 1991, Banner et al. 1993), in which the range of soil moisture regime (SMR) and soil nutrient regime (SNR) conditions are coded on an edatopic grid as follows:

SMR:	SNR: Very poor A	poor B	med-ium C	rich D	very rich E
very xeric 0					
xeric 1					
subxeric 2					
submesic 3					
mesic 4					
subhygric 5					
hygric 6					
subhydric 7					

A “modal site” or “modal ecosystem” refers to those conditions characterized by a more or less mesic SMR and a more or less medium SNR, such that the vegetation expresses the influence of the regional climate more than the influence of local soils and topography. In the individual species treatments, site preferences for individual species (when known) are expressed on the basis of SMR (where 0 is dry and 7 is wet, as above) and SNR (where A is very poor and E is very rich) affinities as documented for different biogeoclimatic subzones in northern B.C. by Beaudry et al. (1999).

Collectively, this information provides the practitioner a good picture of the ecology of these native plants, and where and how you might use them. Some published descriptions have been modified to reflect recent observations and experience of the authors. Where specific information is available, recommendations for row spacing, seeding density and seeding depth are made. If no species-specific information was available, general guidelines gleaned from various guides and propagation manuals are recommended. Sometimes recommendations are made based on information for different species of the same genus and are duly noted as such.

Once again, we emphasize that this manual is a work in progress. The recommendations provided here are undoubtedly inappropriate for many different scenarios, and should not be used as rigid prescriptions. Rather, users of this information are encouraged to experiment and try new approaches for growing, seeding, mixing, and monitoring these and other native plant species. Growers and revegetation practitioners are urged to record their own observations and experience with each species in the space provided for notes after most species descriptions.

Grasses

Agrostis exarata Trin.

spike bentgrass **Family: Poaceae**

Figure 16. Documented range of *Agrostis exarata* in northern British Columbia.

Figure 17. Growth habit of *Agrostis exarata* in cultivation.

Agrostis exarata Trin. spike bentgrass (continued)

Background Information

Douglas et al. (2001b) report that *Agrostis exarata* is found commonly throughout B.C., north to Alaska, the Yukon and Northwest Territories, to southern Saskatchewan and south to Texas, New Mexico, Arizona and California, South America, and is also amphiberingian (i.e., it grows on both sides of the Bering Strait), being found in eastern Asia as well. Earlier literature reported that it was primarily a western grass, occurring from Manitoba, South Dakota, Nebraska, Texas and Mexico, west to the Pacific States, and into British Columbia and Alaska (*Mason 1957, *Hitchcock 1971, *GPFA 1986).

Growth Form: A perennial bunch grass with leaves 2 - 10 mm wide, auricles absent, ligules 3 - 8 mm long; inflorescence 4.5 - 18 cm long, densely covered in spikelets to the base, branches barely visible; spikelets may be awned or awnless on separate plants or in the same inflorescence; mature plant size: 20 - 120 cm tall (Hitchcock 1971, Douglas et al. 1994, Pojar and MacKinnon 1994). It occasionally develops slender rhizomes (*Hickman 1993, *Larson 1993).

Site Preferences: Mesic to wet open fields, at upper levels of beaches and river bars, clearings at low to middle elevations (Douglas et al. 1994, Pojar and MacKinnon 1994). Relatively intolerant of competition and shade, *Agrostis exarata* thrives in open sunny locations and can establish on bare mineral soil, and on forest soils that have been recently harvested of trees (Klinka et al. 1985).

Seed Information

Seed Size: Length: 1.48 mm (1.28 - 1.78 mm).
Width: 0.45 mm (0.38 - 0.52 mm).

Seeds per gram: 26,145 (range: 22,108 – 30,181).

Volume to Weight Conversion: 190.4 g/L at 76.7% purity.

Germination Capacity: At 30°/20° C untreated: 99%.
At 25°/15° C untreated: 75%.
stratified: 13.0%.

Germination Speed: To first germination: 7.3 days.
To 50% potential: 9.9 days.

Seed Longevity: To date, Symbios seeds have been tested after only one year of storage under cool dry conditions, after which they retained their full viability. Link (1993) reports that *Agrostis hyemalis* retains viability for three years or more, and that commercial *Agrostis* seed is often stored more than one year.

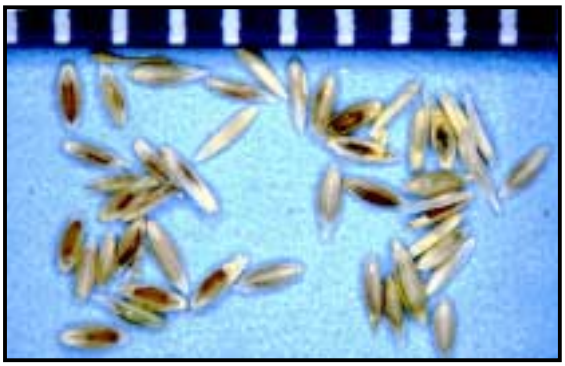

Figure 18. Seeds of *Agrostis exarata*. Rule divisions are 1.0 mm.

Considerations for Growing

Techniques for Seed Production

Storage requirements: Cool dry storage. Link (1993) recommends that seed from the related species, *Agrostis scabra*, should be stored in cloth bags in cool to room temperature.

Seed treatment: Untreated seeds germinate best in warmer soils; does not benefit from stratification.

Soil considerations: Establish on loamy, well prepared soil with a firm seedbed (Gerling et al. 1996).

Agrostis exarata Trin. spike bentgrass (continued)

(Techniques for Seed Production, continued)

Stand establishment: Site should be free of all weeds. Broadleaf weeds can be controlled with the use of a selective broadleaf herbicide without damage to the grass seedlings.
Row spacing: Unknown; suggest 75-120 cm under dryland conditions, 30-90 cm under irrigation.
Seeding density: Unknown at present; suggest 60-100 PLS per linear metre (Smith and Smith 2000).
Seeding depth: 0.5 - 1.5 cm.
Stand maintenance: Regularly cultivate rows and spot spray with herbicide to keep plot weed free; annual fertilization with low N formulations will extend the life of the plot.

Harvesting and Seed Processing
Dates of selective harvesting: In the Bulkley Valley of northwestern B.C., seed has been harvested as early as August 13th. Seed shatters moderately easily.
Hand clipping: Use sharp hand clippers. Hold the seed heads over bins placed alongside the plants being clipped or place a bag over the seed heads before clipping to minimize seed loss.
Vacuum: It is unknown at present if seed can be harvested directly from the stalk with a vacuum. If necessary, use a vacuum immediately after manual or mechanical harvesting to harvest seed that scatters. Plastic placed between the rows will assist this type of salvage harvesting.
Seed stripper: Unknown suitability at present.
For both hand clipping and mechanical harvesting, use of plastic between rows is recommended so any scattered seeds can be salvaged by sweeping or vacuuming.
Combine/thresher settings: 1850 rpm with 3 mm gap; rotary flail if harvested with long stems.
Seed cleaning: Put through fanning mill two times: prescreen 1.2 x 7.1 mm, top 1.8 x 12.7 mm slot, bottom blank; then prescreen 1.5 mm square, top 1.2 x 7.1 mm, bottom 1 mm square.

Considerations for Use in Revegetation

Agrostis exarata has excellent forage value for livestock and wildlife and can be grazed throughout the summer (Stubbendieck et al. 1982).

This species germinates rapidly and has high germination capacity as well, so it is a good candidate species for revegetating mesic to moist degraded lands.

Reproduces primarily from seed, but may also spread laterally by rhizomes (*Sampson et al. 1951, *Hickman 1993).

Agrostis exarata hybridizes with *Agrostis scabra* and *A. stolonifera* (*Welsh et al. 1987).

Agrostis exarata can be used as a soil stabilizer in degraded areas (*Welsh et al. 1987, Gerling et al. 1996).

This species grows well on soils derived from schists, limestones, sandstones and conglomerates (*Severson and Thilenius 1976).

* *fide* Esser 1994a

Agrostis exarata Trin. **spike bentgrass**
(continued)

Notes

Bromus ciliatus L.
fringed brome **Family: Poaceae**

Figure 19. Documented range of *Bromus ciliatus* in northern British Columbia.

Figure 20. Growth habit of *Bromus ciliatus* in cultivation.

Figure 21. Inflorescence of *Bromus ciliatus*.

Bromus ciliatus L. fringed brome (continued)

Background Information

Bromus ciliatus is found north to Alaska, the Yukon and Northwest Territories, east to Newfoundland and south to North Carolina and Mexico. It is frequent in British Columbia in, and east of, the Coast-Cascade Mountains (Douglas et al. 2001b). As recognized by Douglas et al. (2001b), *Bromus ciliatus* includes *B. canadensis* Michx. and *B. richardsonii* Link, which may be treated as subspecies but are not distinguished here.

Growth Form: Slender loosely tufted plant, frequently with hairy nodes on the stems; leaves are lax, flat, and hairy on at least one surface; no auricles; ligules 1 mm long; inflorescence a drooping open panicle with few flowered spikelets and awn 2-4 mm long; large fuzzy seeds; mature plants are 60-100 cm tall (MacKinnon et al. 1992, Pojar and MacKinnon 1994). *Harper et al. (1992) report that *Bromus ciliatus* has a well developed root system.

Site Preferences: Moist to dry streambanks and lakesides, mesic meadows and open forests and dry rocky slopes at low to medium elevations in the northern Interior (MacKinnon et al. 1992, Douglas et al. 1994).

Seed Information

Seed Size: Length: 16.38 mm (13.97 - 18.66 mm)
Width : 3.14 mm (2.56 - 3.65 mm)

Seeds per gram: 420 (range: 263 - 604)

Volume to Weight Conversion: 97.2 g/L at 97.2% purity

Germination Capacity: At 30°/20° C untreated: 71.4% (57 - 84%)
At 25°/15° C untreated: 57.7% (25 - 90%)
stratified: 59.2% (23 - 95%)

Germination Speed: To first germination: 12.4 days
To 50% potential: 14.4 days

Seeds are nondormant (*Hoffman 1985).

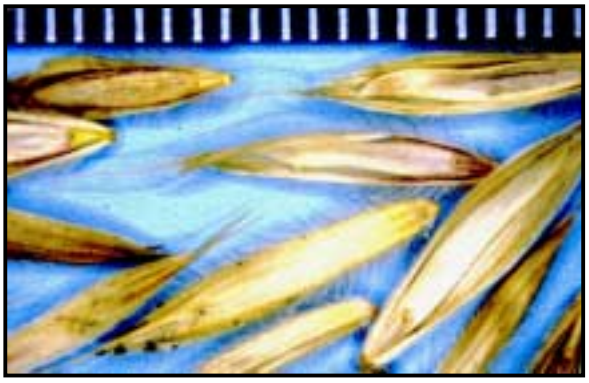

Figure 22. Seeds of *Bromus ciliatus*. Rule divisions are 1.0 mm.

Seed Longevity: In our research, seeds retained their viability after two years of storage under cool dry conditions.

Considerations for Growing

Techniques for Seed Production

Seed treatment: No seed stratification needed for optimal germination.

Soil considerations: Establish stand on a loamy firm seedbed; tests indicate best germination under warm conditions.

Stand establishment: Site should be free of all weeds. Broadleaf weeds can be controlled with the use of a selective broadleaf herbicide without damage to the grass seedlings.

Row spacing: Suggest 30 to 90 cm.

Seeding density: 100-130 PLS seeds per linear metre.

Seeding depth: 0.6-1.2 cm (Pahl and Smreciu 1999).

Stand maintenance: Regularly cultivate rows and spot spray with herbicide to keep plot weed free; annual fertilization with low N formulations will extend the life of the stand, although lodging may be a problem if over-fertilized (Pahl and Smreciu 1999).

Bromus ciliatus L. fringed brome (continued)

Harvesting and Seed Processing

Dates of selective harvesting in the Bulkley Valley of northwestern B.C. have ranged from August 30th to October 19th.

Hand clipping: Hold the seed heads over bins placed alongside the plants being clipped. Unripe seeds can mature to some degree if allowed to cure after clipping.

Vacuum: Not suitable for direct harvesting. If necessary, use the vacuum immediately after manual or mechanical harvesting to harvest seed that scatters. Plastic placed between the rows will assist this type of salvage harvesting.

Seed stripper: Harvest when the seeds are ripe but place plastic between the rows to minimize seed loss; seeds appear to be damaged easily, so a soft-threaded harvesting head should be used. According to Pahl and Smreciu (1999), the shattering potential of this species is high. In our experience the seed shatters moderately easily when windy.

For both hand clipping and mechanical harvesting, plastic between rows is recommended so any scattered seeds can be salvaged by sweeping or vacuuming.

Note: This species does not ripen uniformly on the stem, yet ripe seeds are easily lost. So several selective harvests may be needed, or the crop can be swathed or clipped when approximately half of the seeds appear ripe (usually in September), followed by drying outdoors in the sun, or indoors in a warm dry area.

Combine/thresher settings: Not used as a primary threshing mechanism because the cylinder seems to damage the seeds; use rotary flail; hold stalks with seed heads attached against rotary flail.

Seed cleaning: After threshing, put roughly cleaned seeds and detached heads through fanning mill screens two times: prescreen, 2.5 x 19 mm slot; top, 4 x 19 mm slot; bottom, 1 mm square. If some seeds are still attached to seed heads, these can optionally be run through a rethresher.

Storage requirements: Cool dry conditions.

Considerations for Use in Revegetation

Bromus ciliatus is considered effective for erosion control (Gerling et al. 1996, Pahl and Smreciu 1999). *Boggs et al. (1990) rate the potential for short-term revegetation and erosion control as medium and the long-term revegetation potential as high.

This species has been found growing naturally on coal mine spoils in Alberta (Strong et al. 1978).

Bromus ciliatus is considered highly palatable and is reported to have excellent forage value for livestock and wildlife (*Humphrey 1960, *Mattson 1984, *Larson and Moir 1987, *Welsh et al. 1987, *Boggs et al. 1990, Gerling et al. 1996). However, Boggs et al. (1990) report that its energy rating is only fair and its protein content is poor.

Bromus ciliatus is reported to grow on mesic soils in Alberta (Gerling et al. 1996).

Seeds of *Bromus ciliatus* provide food for small mammals, turkeys and other birds (*Larson and Moir 1987, Harper et al. 1992).

Bromus ciliatus increased in cover one year after harvest, but then fluctuated in post-harvest years two to five (*Crouch 1985).

* *fide* Esser 1994a

Bromus ciliatus L. **fringed brome**
(continued)

Notes

Calamagrostis canadensis (Michx.) Beauv.
bluejoint reedgrass **Family: Poaceae**

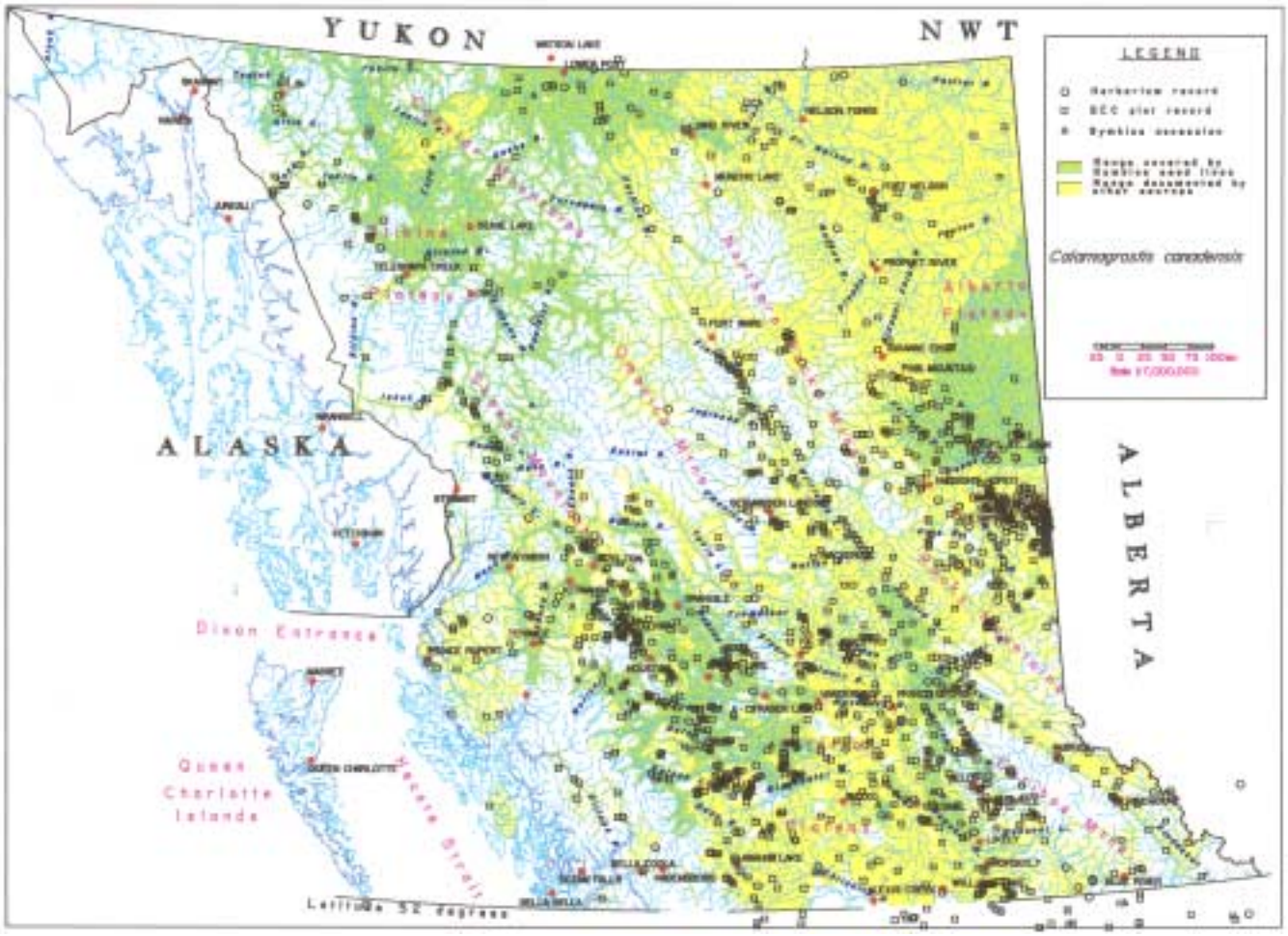

Figure 23. Documented range of *Calamagrostis canadensis* in northern British Columbia.

Figure 24. Growth habit of *Calamagrostis canadensis* in cultivation.

Calamagrostis canadensis (Michx.) Beauv. bluejoint reedgrass (continued)

Background Information

Calamagrostis canadensis is a circumboreal species found north to Alaska, Yukon and the Northwest Territories, east to Newfoundland and south to Mexico and North Carolina, and is also found throughout Eurasia. Two varieties are recognized in B.C., though we do not distinguish them in this treatment: *C.c.* var. *canadensis* is common throughout British Columbia east of the Coast-Cascade Mountains, but is rare in coastal B.C.; *C.c.* var. *langsdorfii* is common in northern British Columbia east of the Coast-Cascade Mountains, but is less frequent southward (Douglas et al. 2001b). This species has been reported to be the most common and widespread *Calamagrostis* species in North America (*USFS 1937). Work in progress (R. Hebda pers. comm.) suggests that pollen of this species is often sterile, especially in populations found in wetlands, but viable seed is nevertheless produced apomictically.

Growth Form: Long-lived rhizomatous tufted coarse grass; leaves lax, collars hairless, auricles lacking, ligules 3-8 mm long; nodding flowering head 10–25 cm long often turning purplish; mature plant size is 60–120 cm tall. In Alaska, it may reach heights of up to 200 cm (Hardy 1989, MacKinnon et al. 1992).

Site Preferences: Moist to wet bogs, meadows and open forests at low to high elevations (Douglas et al. 1994). In B.C. it is reported to be extremely winter hardy, tolerant of flooding and saturated soils, tolerant of drought, shade-tolerant to shade intolerant, abundant in pioneer and young seral stages, especially if mineral soil has been exposed (Beaudry et al. 1999). It is found on poor to very rich sub-mesic to sub hydric sites in the SBSx or SBSd subzones, medium to very rich hygric and subhydric sites in the SBSw or SBSv subzones, and mesic to subhydric very poor to very rich sites in the SBSm subzones; sub-hygric to hydric poor to very rich sites in the BWBSx or BWBSd subzones, submesic to subhydric poor to very rich sites in the BWBSm subzones and submesic to hygric poor to rich sites in the BWBSw or BWBSv subzones; on mesic to hygric medium to very rich sites in the ESSFx or ESSFd subzones, submesic to subhydric poor to very rich sites in the ESSFm subzones and subhygric to subhydric medium to very rich sites in the ESSFmk; on subhygric to subhydric poor to very rich sites in the SBPSx or SBPSd subzones, submesic to subhydric poor to very rich sites in the SBPSmc and subhygric to subhydric poor to very rich sites in the SBPSmk (Banner et al. 1993, Beaudry et al. 1999).

Seed Information

Seed Size: Length: 2.97 mm (2.50 - 3.64 mm)
Width : 3.34 mm with callus hair (2.04 - 5.01 mm)
without callus hair 0.51 mm

Seed per gram: 15,312 (range: 9,115 – 24,370)

Volume to Weight Conversion: 28.2 g/L at 34.0% purity

Germination Capacity: At 30°/20° C untreated: 42.5%
At 25°/15° C untreated: 17.6 (6 - 40%)
stratified: 2.0% (0.3 - 4%)

Germination Speed: To first germination: 15.4 days
To 50% potential: 22.0 days

Figure 25. Seeds of *Calamagrostis canadensis*. Rule divisions are 1.0 mm.

Calamagrostis canadensis (Michx.) Beauv. bluejoint reedgrass (continued)

(Seed Information, continued)

Seed Longevity**:** Conn and Farris (1995) and Hardy BBT (1989) report that *Calamagrostis canadensis* seed can remain viable in the soil for up to seven years. Germination capacity of seed tested by Symbios Research in the year it was harvested has been low, however Link (1993) reports germination >84% in seed stored for at least two years after collection and storage. Though germination levels were not quantified, we have very successfully germinated seed 4 to 6 years old.

Considerations for Growing

Techniques for Seed Production

Seed treatment: Untreated seeds germinate best in warmer soils. We did not find stratification beneficial, though Young and Young (1986) report that cool moist stratification may increase germination.

Soil considerations: Soil should be planted in the spring and should be moist to saturated at the time of planting, but with no standing water (Link 1993). When growing in the wild, this species is frequently found growing in peaty soils (Tesky 1992).

Stand establishment: Site should be free of all weeds. Broadleaf weeds can be controlled with the use of a selective broadleaf herbicide without damage to the grass seedlings. Young and Young (1986) report that fertilization may improve seedling emergence and establishment. Link (1993) reports that *Calamagrostis canadensis* establishes best by rhizome. MacDonald and Lieffers (1991) and *Powelson and Lieffers (1991) state that this species produces an extensive network of rhizomes during a single growing season.

Row spacing: Unknown; suggest 75-120 cm under dryland conditions, 30-90 cm under irrigation.

S*eeding density*: Unknown at present; suggest 60-100 PLS per linear metre (Smith and Smith 2000).

Seeding depth: 0.6-1.2 cm.

Stand maintenance: Regularly cultivate rows and spot spray with herbicide to keep plot weed free; annual fertilization with low N formulations will extend the life of the plot, although it may not be necessary with this species since stands in the wild are reported to persist for long periods, possibly as long as 100 years under suitable site conditions (Hardy 1989).

Harvesting and Seed Processing:

Since this species exists in nearly pure stands on poorly drained clearcut sites, the opportunity exists to harvest seed in the wild.

Dates of selective harvesting in the Bulkley Valley of northwestern B.C. range from September 10th to October 17th. Ringius and Sims (1997) report that seed set occurs from mid-August to late September. This species holds on to its seed well.

Hand clipping: Harvest manually with a hand sickle or clippers when most seeds are ripe in late August (Pahl and Smreciu 1999), followed by drying in the sun or indoors in a warm dry area.

Vacuum: It is unknown at present if seed can be harvested directly from the stalk with a vacuum. If necessary, use a vacuum immediately after manual or mechanical harvesting to glean seed that scatters. Plastic placed between the rows will assist this type of salvage harvesting.

Seed stripper: Harvest with a seed stripper (using a soft-threaded harvesting head) when most seeds seem ripe; freshly harvested seed should then be dried or cured further.

Calamagrostis canadensis (Michx.) Beauv. bluejoint reedgrass (continued)

(Harvesting and Seed Processing, continued)

For both hand clipping and mechanical harvesting, plastic between rows is recommended so any scattered seeds can be salvaged by sweeping or vacuuming.
Combine/thresher settings: 1548 rpm with 5 mm gap.
Seed cleaning: Rotary flail works well if seed is harvested with long stalks. Clean further using a fanning mill: prescreen, 4 x 19 mm slot; top, 4.98 mm round; bottom blank; use hand to rub the seed through the screens as the seed balls together.
Storage requirements: Link (1993) reports that this species can survive dry storage at room temperature, but seeds stored for long periods survive best under cool, dry conditions (0.6–7.2^{o} C).

Considerations for Use in Revegetation

Due to its aggressive rhizomatous nature, this species provides good erosion control and is considered particularly important on higher gradient streams where there is seasonal flooding (Hardy 1989, *Boggs et al. 1990).

C. canadensis is found growing naturally on coal mine spoils in Alberta (Strong et al. 1978).

This species has also been noted to invade oil spill sites in the Northwest Territories and is reported to recover rapidly after spills (Hardy 1989).

In Alberta, *Calamagrostis canadensis* is reported to grow on fine to coarse textured wet to mesic soils, and to be tolerant of extremely acidic soils, flood, drought and saline conditions (Hardy 1989, Gerling et al. 1996). *Calamagrostis canadensis* is reported by Douglas et al. (1994) and Gerling et al. (1996) to have fair to moderate forage value for cattle. Others report that it provides a large amount of forage for many big game species and livestock (*USFS 1937, *Herzman et al. 1959, Hardy 1989).

Hogg and Lieffers (1991) report that this species is an important forage for livestock in Alaska and an important component in the diet of bison herds in the Slave River lowland in the Northwest Territories; however, it can be sensitive to overgrazing (Hardy 1989).

The low germination rates of filled seeds suggests a dormancy mechanism, but its widespread success suggests long-term viability in the seedbank (Lieffers et al. 1993).

Calamagrostis canadensis seedlings do well in sheltered sites on moist mineral soil or decomposed organic soil (Lieffers et al. 1993).

Developing seedlings of this species do not tolerate drought well but are drought tolerant once established (Mueller-Dombois and Sims 1966, Lieffers et al. 1993).

The root system of this species tolerates low soil temperatures, so it is suitable for revegetation of cold sites (Hardy 1989).

Some strains of *Calamagrostis canadensis* are susceptible to "white top" (Hardy 1989).

Calamagrostis canadensis tends to be a silviculturally competitive species in much of northeastern B.C. and northern Alberta and on moist disturbed sites (Haeussler et al. 1990, Hogg and Lieffers 1991).

Stands of this species can produce thick litter, which covers the soil surface causing decreased soil temperature (Hogg and Lieffers 1991).

* *fide* Tesky 1992.

Calamagrostis rubescens Buckl.

pinegrass **Family: Poaceae**

Figure 26. Documented range of *Calamagrostis rubescens* in northern British Columbia.

Figure 26a. Growth habit of *Calamagrostis rubescens* in the wild.

Calamagrostis rubescens Buckl. pinegrass (continued)

Background Information

Calamagrostis rubescens is found east to Alberta and south to Colorado, Utah, Nevada and California; it is common in southern British Columbia, east of the Coast-Cascade Mountains (Douglas et al. 2001b). It is found at lower elevations and warmer topographic exposures in northern B.C. Rose et al. (1998) report that its range extends east into Manitoba.

Growth Form: Rhizomatous grass with a reddish base, ring of hairs where the leaf meets the stem; leaves 2-4 mm wide, collars hairy, auricles absent; ligules to 5 mm long; dense panicle of yellowish green to purple inflorescence 7-15 cm long; mature plant size is 60 - 100 cm tall (Haeussler et al. 1990, MacKinnon et al. 1992).

Site Preferences: Mesic to dry rocky or sandy sites, dry woods, and clearings at low to medium elevations in the southernmost part of the northern Interior (Douglas et al. 1994, MacKinnon et al. 1992). In B.C. it is reported to be tolerant of moderate winter temperatures and frost, tolerant of low nitrogen levels once it is established, tolerant of drought and high air temperatures, shade tolerant to shade intolerant (Beaudry et al. 1999). It is found on xeric to subhygric very poor to rich sites in the SBSx or SBSd subzones, xeric to mesic, very poor to rich sites in the SBSm subzones and xeric poor sites in the SBSw or SBSv subzones; subxeric to submesic very poor sites in the BWBS zone; subxeric to submesic poor to very rich sites in the ESSF zone; xeric to subhygric very poor to very rich sites in the SBPSx or SBPSd subzones and in the SBPSmk (Banner et al.1993, Beaudry et al. 1999). It is a seral species, invading and dominating on suitable clear-cut sites until the canopy closes, but remains dominant in the understory of open-canopied lodgepole pine and Douglas-fir stands (Champion 2000).

Seed Information

Seed Size: Length: 4.67 mm (3.58 - 6.13 mm)
Width : 0.85 mm (0.67 - 1.00 mm)
Seeds per gram: 8,730 (range: 7,191 - 9,500)
Volume to Weight Conversion: Unknown
Germination Capacity: At 30°/20° C untreated: 19.7% (6- 42%)
At 25°/15° C untreated: 21.0%
Germination Speed: To first germination: 12.1 days
To 50% potential: 15.5 days
Seed Longevity: Unknown

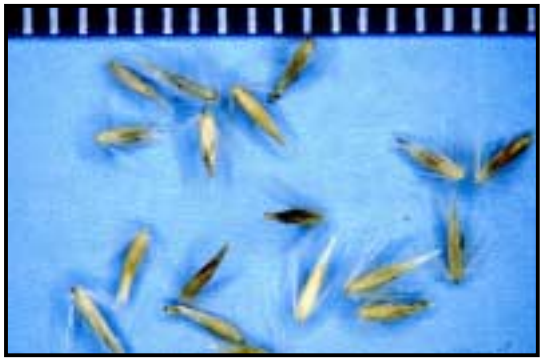

Figure 27. Seeds of *Calamagrostis rubescens*. Rule divisions are 1.0 mm.

Calamagrostis rubescens Buckl. pinegrass (continued)

Considerations for Growing

Techniques for Seed Production

Seed treatment: No pre-germination treatments required.
Soil considerations: Establish on loamy, well prepared soil with a firm seedbed.
Stand establishment: Site should be free of all weeds. Broadleaf weeds can be controlled with the use of a selective broadleaf herbicide without damage to the grass seedlings.
Row spacing: Unknown, suggest 75-120 cm under dryland conditions, 30-90 cm under irrigation.
Seeding density: Unknown at present, suggest 60-100 PLS per linear metre (Smith and Smith 2000).
Seeding depth: 0.6 - 1.2 cm.
Stand maintenance: Regularly cultivate rows and spot spray with herbicide to keep plot weed free; annual fertilization with low N formulations may extend the life of the plot. *Calamagrostis rubescens* seems much more sensitive than *C. canadensis* to competition from weeds; stands were not easy to maintain in the Bulkley Valley of northwestern B.C.

Harvesting and Seed Processing:

Hand clipping: Harvest with a hand sickle or clippers when seeds are ripe (Pahl and Smreciu 1999), followed by drying outdoors in the sun, or indoors in a warm dry area.
Vacuum: It is unknown at present if seed can be harvested directly from the stock with a vacuum. If necessary, use a vacuum immediately after manual or mechanical harvesting to harvest seed that scatters. Plastic placed between the rows will assist this type of salvage harvesting.
Seed stripper: Harvest mechanically when seeds are ripe (Pahl and Smreciu 1999), followed by drying outdoors in the sun, or indoors in a warm dry area.
Combine/thresher settings: 1548 rpm with 5 mm gap.
Seed cleaning: Put through fanning mill after threshing: top screen, 4 x 19 mm slot; bottom screen, 4.98 mm round; use hand to rub the seed through the screens, as the fluff balls together.
Storage requirements: Cool dry conditions.

Considerations for Use in Revegetation

Calamagrostis rubescens is not considered highly palatable to grazing animals, except for new spring growth (MacKinnon et al. 1992).

If grazing is a consideration, nitrogen applications of 200 and 300 kg/ha will increase forage yield and crude protein concentrations. Phosphorous and sulfur should be applied at 55 kg/ha for increased forage value (Champion 2000).

In Alberta this species is reported to grow on medium to coarse textured mesic to dry soils and to be drought tolerant (Gerling et al. 1996).

In B.C. it is found on sites with a wide variety of well drained loamy to coarse textured soils (Haeussler et al. 1990).

The fine root system of this species can provide excellent control of surface soil erosion (Haeussler et al. 1990).

This species tolerates trampling well, so is a good candidate for use on or near trails (*Cole 1978, 1981).

fide Champion 2000.

Calamagrostis rubescens Buckl. pinegrass (continued)

Notes

Elymus glaucus Buckl. ssp. *glaucus*
blue wildrye **Family: Poaceae**

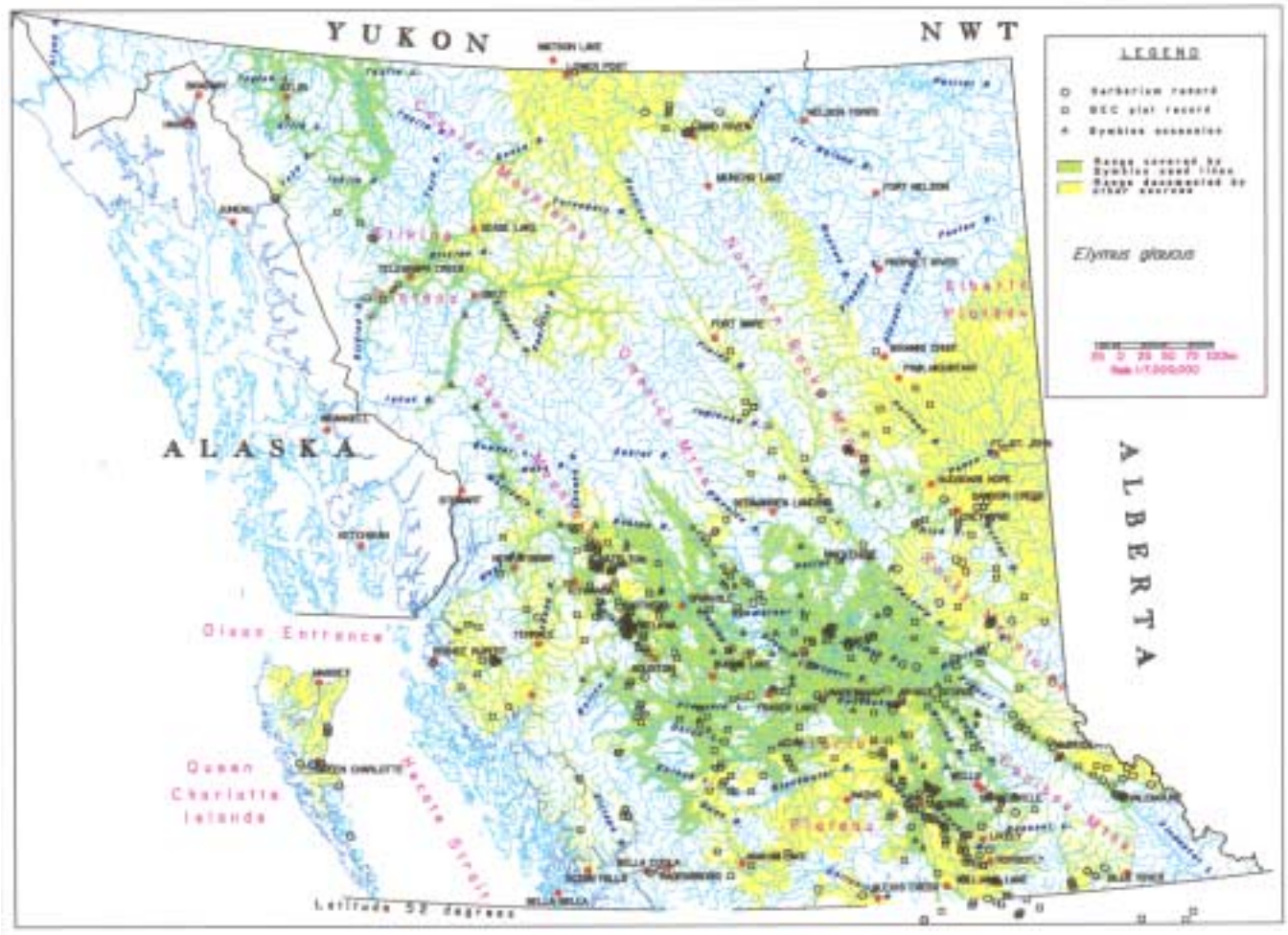

Figure 28. Documented range of *Elymus glaucus* in northern British Columbia.

Figure 29. Cultivated stand of *Elymus glaucus*.

Figure 30. Close-up of *Elymus glaucus* seed heads.

Elymus glaucus Buckl. ssp. *glaucus* (continued) — blue wildrye

Background Information

Elymus glaucus is found in southeast Alaska and the Yukon, east to Ontario and south to New York, Illinois, Arizona, Texas, New Mexico, Arkansas, and California. There are three subspecies: *E.g.* ssp. g*laucus* is common in southern B.C., but is less frequent north of 55°; the short-awned *E.g.* ssp. v*irescen*s (Piper) A. Love is more likely to be found on the coast (Douglas et al. 2001b); and *E.g.* ssp. *jepsonii* (Burtt Davy) Gould is not recognized in B.C. (*Hickman 1993, *Kartesz 1994). In northern B.C., our plants are largely *E.g.* ssp. *glaucus*, and all of those with which we have worked have had characteristically long awns, but we do not distinguish among subspecies in this treatment or in the range mapped in Figure 28. In the United States, this species has been considered the most widely distributed of the western wildryes (*USDA 1937, Hoover et al. 1948).

Growth Form: Culms in loose to dense tufts, often bent at the base (Hitchcock 1971); forms small clumps; leaves broad (4-13 mm wide) lax, flat or slightly inrolled; has well-developed claw-like clasping auricles; ligules a uniform 1 mm; stiff inflorescence 5-15 cm long, conspicuous awned spikes, sometimes purplish but dense; mature plant size: 50-150 cm tall (MacKinnon et al. 1992). *Elymus glaucus* may produce rhizomes (*GPFA 1986), or stolons (*Hickman 1993).

Site Preferences: Moist to dry slopes, meadows and open forests at low to medium elevations (Douglas et al. 1994, MacKinnon et al. 1992). It has a tendency to decrease in frequency with increasing elevation (Klinka et al. 1989). In B.C. it is reported to be shade-tolerant to very shade-tolerant, to persist in deciduous young and mature seral forests (Beaudry et al. 1999). In northern B.C. it is found on mesic to hygric medium to very rich soils in the SBSx or SBSd subzones, subhygric to hydric medium to rich sites in the SBSm subzones, subhygric rich to very rich sites in the SBSw or SBSv subzones, and on mesic to hygric, medium to very rich sites in the SBPSmk (Beaudry et al. 1999). In coastal B.C. it is reported to grow on moderately dry to fresh nitrogen-rich soils (moder and mull humus forms), is sporadic in coniferous forests, on floodplain and stream-edge sites (Klinka et al. 1989).

Seed Information

Seed Size: Length: 29.98 mm (20.91 - 38.88 mm)
Length without awn: 11.35 mm (9.98 - 13.34 mm)
Width: 1.75 mm (1.47 - 2.14 mm)

Seeds per gram: 219 (range: 189 - 243)

Volume to Weight Conversion: 149.2 g/L at 93.8% purity

Germination Capacity: At 30°/20° C untreated: 74.1% (52% - 89%)
At 25°/15° C untreated: 79.2% (75 - 83%)
stratified: 82.0% (75 – 89%)

Germination Speed: To first germination: 9.5 days
To 50% potential: 9.7 days

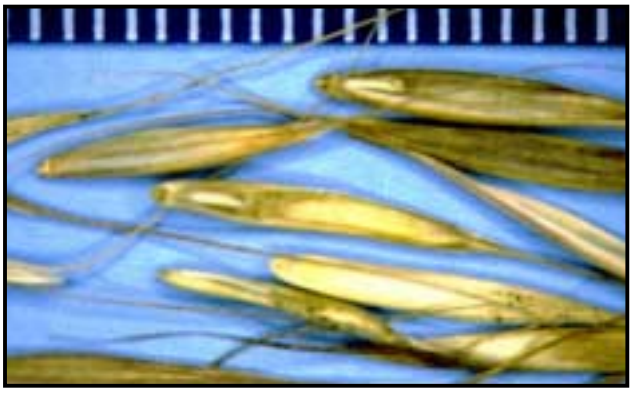

Figure 31. Seeds of *Elymus glaucus*. Rule divisions are 1.0 mm.

Seed Longevity: Link (1993) reports that seeds can be stored at least four to five years in controlled low temperature, under low humidity conditions. Archibald et al. (2000) report that seed has remained viable for at least eight years if stored at +1°C or –17°C.

Elymus glaucus Buckl. ssp. *glaucus* blue wildrye (continued)

Considerations for Growing

Techniques for Seed Production

Seed treatment: Germinates well under most conditions, though we have found stratification to be marginally beneficial. Other researchers report that seeds generally do not need pretreatment to successfully germinate (Young and Young 1986, Rose et al. 1998, Archibald et al. 2000).

Soil considerations: Establish on loamy, well-prepared soils with a firm seedbed.

Stand establishment: Site should be free of all weeds. Broadleaf weeds can be controlled using a selective broadleaf herbicide without damage to grass seedlings or the established plants. Link (1993) reports that weed control is most critical during seedling establishment. A high-N starter fertilizer is recommended, followed by a complete fertilizer when plants are well established (Darris et al. 1996). Archibald et al. (2000) have employed multiple fertilizer applications per season.

Row spacing: Suggest 30 to 90 cm; Archibald et al. (2000) use 30 cm spacing in raised beds.

Seeding density: 25-50 PLS per linear metre; Archibald et al. (2000) use 33-40 PLS/m.

Seeding depth: 0.6-2.5 cm, spring or fall seeding (Plummer 1943, Rose et al. 1998); Archibald et al. use surface sowing followed by a 6-8 mm top dressing of sawdust.

Stand maintenance: Regularly cultivate rows and spot spray with herbicide to keep plot weed free; annual fertilization with low N formulations will extend the life of the plot. We noted seed production decreasing after five years, primarily due to ingrowth by other grasses; Archibald et al. (2000) report fairly constant yields of approximately 220 kg/ha for four years. When grown on moist sites, *Elymus glaucus* is apparently susceptible to ergot infection; no control is recommended, but ergoty seeds should be screened from seed lots as soon as possible to minimize contamination.

Harvesting and Seed Processing

Dates of selective harvesting in the Bulkley Valley of northwestern B.C. range from August 9th to October 25th. Watch carefully for seeds to ripen (harden), as they shatter very easily.

Hand clipping: Harvest with a hand sickle or clippers when seeds are ripe in late August followed by drying outdoors in the sun, or indoors in a warm dry area. Link (1993) and Knapp and Rice (1996) report that seed collected prematurely develop to maturity after harvesting, better than many other grass species; this makes clipping or swathing followed by curing a practical means of facilitating a single seed harvest (Archibald et al. 2000). Plastic placed between rows will enable you to harvest shattered seeds with a vacuum.

Vacuum: It is unknown at present if seed can be efficiently harvested directly from the stock with a vacuum. If necessary, use a vacuum immediately after manual or mechanical harvesting to glean seed fallen to the ground; plastic placed between the rows will assist this type of salvage harvesting.

Seed stripper and mechanical harvesting: In our experience, a fair amount of seed gets scattered when harvesting with the seed stripper, but this might be dealt with using softer threads, lower rpm, or an auxiliary vacuum attachment. Use of a sickle-bar mower or swather when approximately half of the seeds are ripe, followed by field curing, is recommended for larger fields.

Combine/thresher settings: 1548 rpm with 10 mm gap.

Seed cleaning: Rotary flail works best when seed is harvested with long stalks. Then run through a fanning mill twice with the following configurations: prescreen 4 x 19 mm slot; top screen 2.5 x 19 mm slot; bottom screen 1.2 x 7.1 mm slot. Then run through a vacuum separator at near-high suction. Archibald et al. (2000) recommend de-awning prior to additional seed handling.

Elymus glaucus Buckl. ssp. *glaucus* blue wildrye (continued)

(Harvesting and Seed Processing, continued)

Storage requirements: Cool dry conditions; Archibald et al. (2000) dry seed to 5-8% moisture content first, and then store in coolers (1°C) or in freezers (-17°C).

Considerations for Use in Revegetation

This species grows best on moderately moist soils (*USFS 1937, *Hoover et al. 1948, *Sampson et al. 1951).

In Alberta this species is reported to grow on medium to coarse textured mesic to dry soils and to be tolerant of alkaline soil conditions (Gerling et al. 1996).

Others report that *Elymus glaucus* is sensitive to saline soils and not tolerant of shallow soils (*Plummer et al. 1968 and *Hassell et al. 1983).

This species has a hardy fibrous root system which penetrates deeply so is good for erosion control (*Hickman 1993).

Elymus glaucus is recommended for erosion control on steep, eroded slopes, roadsides or fire damaged sites as a pioneer species (Darris et al. 1996). Our field trials have corroborated these recommendations, with *E. glaucus* establishing well over two growing seasons on steep gravelly slopes.

Elymus glaucus has a well developed root system, but it is intolerant of continued heavy grazing (Johnson 1999).

Elymus glaucus provides forage for domestic stock and wildlife, especially its new growth. (*Hoover et al. 1948, Hitchcock 1971, *Hassell et al. 1983, MacKinnon et al. 1992). But its forage value is only rated as fair because of its coarse foliage.

This species is rated good for energy value and poor for protein value (*Dittberner and Olson 1983).

In our research trials, *Elymus glaucus* appears to compete well with *Phleum pratense.*

Stands are reported to decline dramatically after three to four years (*Hassell et al 1983).

Elymus glaucus hybridizes with *E. elymoides*, *E. stebbinsii* and *E. trachycaulus* (*Hickman 1993).

Although this species is available through commercial producers, *Libby and Rodrigues (1992) caution that such seed should be used sparingly to avoid genetic dilution of local populations.

According to Knapp and Rice (1996) this species is predominantly self-pollinating, but Ie (2000) reports that B.C. populations exhibit up to 50% outcrossing (Ie 2000).

*Hassell et al. (1983) report that *Elymus glaucus* is compatible with tree regeneration.

This species is very promising; it is easy to grow and the seed is of a good size and is easy to harvest and clean; it establishes well from seed under a wide range of environmental conditions. It can fill the role of a tall-statured grass species for most revegetation purposes in northern B.C.

**fide* Johnson 1999.

Other Considerations

The seeds of *Elymus glaucus* were used historically as food by the Salish people on Vancouver Island (Turner and Bell 1971).

Elymus trachycaulus (Link) Gould ex Shinners ssp. *trachycaulus*
slender wheatgrass **Family: Poaceae**

Figure 32. Documented range of *Elymus trachycaulus* in northern British Columbia.

Figure 33. Growth habit of *Elymus trachycaulus* in cultivation.

Figure 34. Harvesting a ripe stand of *Elymus trachycaulus* using a hand sickle.

Elymus trachycaulus ssp. *trachycaulus* slender wheatgrass (continued)

Background Information

Elymus trachycaulus is found north to Alaska, the Yukon and Northwest Territories and east to Newfoundland, south to North Carolina, Indiana, Missouri, California and Mexico. Two subspecies are found in B.C., the awned *E.t.* ssp. *subsecundum*, and the unawned *E.t.* ssp. *trachycaulus*. This discussion refers solely to the unawned subspecies, which is common throughout B.C. (Douglas et al. 2001b).

Growth Form: Flat leaves 2-4 mm wide, with short or no auricles and very short ligules; slender spike with spikelets overlapping, no awns; somewhat rhizomatous; mature plant size: 50 - 90 cm tall (Hitchcock 1971, Hardy 1989, MacKinnon et al. 1992). The root system is dense, with both coarse and fine fibrous roots, which can extend beyond 30 cm in depth (Howard 1992). There are at least three subspecies and six varieties of this species, which differ in awn length, size and culm length and crowding of spikelets (*Kartesz and Kartesz 1980, Hardy 1989, *Lackschewitz 1991). It is both self-pollinated and wind-pollinated (Howard 1992). It is important to differentiate between this native species and the exotic *Elymus repens* (quack grass, also known as *Agropyron repens*), which looks similar. *Elymus repens* has well developed auricles and rhizomes and is considered a regionally noxious weed (Cranston et al. 2002).

Site Preferences: Dry to moist sites in grasslands, meadows, rocky slopes, and open forests at low to medium elevations throughout the northern Interior. In northern B.C., it is reported to be shade intolerant and to be a species of open grasslands and shrub steppes. Grows on xeric to subxeric, medium to very rich sites in the SBSx or SBSd subzones and the BWBSx or BWBSd subzones (Beaudry et al. 1999). In Alberta, reported to grow on medium textured, mesic to dry soils, and to be tolerant of drought, flood, saline and alkaline conditions (Gerling et al. 1996). Reported to generally be a subdominant species in subalpine forests (Willard 1990), it is nonetheless one of the major components of northern British Columbia grasslands (Pojar 1982). It is a pioneer species on gravel slopes, abandoned coal mine sites and burned pine forests (**Ellison 1954, **Bartos and Mueggler 1981, **Russell 1985, **Fox and Allen 1995).

Seed Information

Seed Size: Length: 10.41 mm (8.04 - 12.46 mm)
Width : 1.82 mm (1.31 - 2.63 mm)

Seeds per gram: 353 (range: 266 - 423)

Volume to Weight Conversion: 217.8 g/L at 95.7% purity

Germination Capacity: At 30°/20° C untreated: 72.3% (59 - 94%)
At 25°/15° C untreated: 81.9% (77 - 87%)
stratified: 88.2% (83 – 93%)

Germination Speed: To first germination: 11.4 days
To 50% potential: 16.2 days

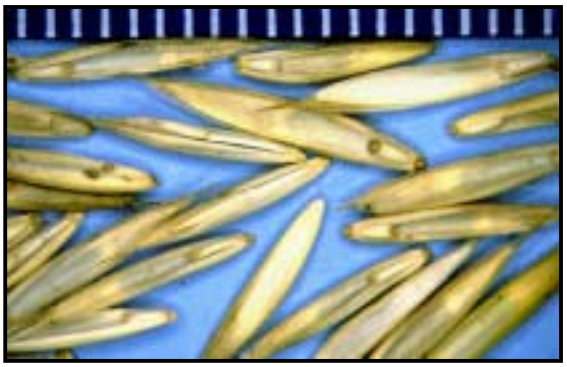

Figure 35. Seeds of *Elymus trachycaulus*. Rule divisions are 1.0 mm.

Seed Longevity: Seed in seed banks is reported to remain viable for three to six years with a germination capacity of 80 to 90% (Howard 1992).

Elymus trachycaulus ssp. *trachycaulus* slender wheatgrass (continued)

Considerations for Growing

Techniques for Seed Production

Seed treatment: Our germination tests indicate that this species responds positively to stratification. This confirms suggestions by Paulsen (*1970) and Fulbright (*1982) that it requires a 1 to 2 month period of short night/long day stratification prior to germination.

Stand establishment: Requires a moderately moist mineral seedbed, or a lightly mulched firm seedbed (*Fulbright et al 1982, Hardy 1989). The site should be free of all weeds, although dicot weeds can be sprayed with a selective broadleaf herbicide with no apparent damage to vegetative or seed yields of *Elymus trachycaulus*.

Row spacing: 30-90 cm (Pahl and Smreciu 1999); Smith and Smith (2000) recommend 90 cm spacing in dryland areas and 60 cm row spacing on irrigated sites.

Seeding density: 82-100 PLS per linear metre.

Seeding depth: 1.2-1.8 cm (Pahl and Smreciu 1999, Smith and Smith 2000); spring seeding is best, and fertilization at the time of planting would be advantageous (Hardy 1989).

Stand maintenance: Regularly cultivate rows and spot spray with herbicide to keep plot weed free; annual fertilization with low N formulations will extend the life of the plot. *Elymus trachycaulus* is generally considered a short-lived perennial with a life span of five years (Knowles 1987).

Harvesting and Seed Processing

Note: It is critical that any quack grass (*Elymus repens*) in the stand be completely rogued out before harvesting, as its seeds cannot be mechanically separated from those of *Elymus trachycaulus* if the crop is contaminated.

Dates of selective harvesting in the Bulkley Valley of northwestern B.C. have ranged from August 25th to August 30th. Timing of harvest is important, as the seed shatters easily when ripe.

Hand clipping: Manual harvest with a hand sickle (Fig. 34) or clippers when the seeds are ripe in late August or early September, followed by drying outdoors in the sun, or indoors in a warm dry area.

Vacuum: This grass species does not release seeds as readily as many others, so it is unlikely that vacuum seeding would be effective. If necessary, use a vacuum cleaner immediately after manual or mechanical harvesting to harvest seed that falls to the ground; plastic placed between the rows will assist this type of salvage harvesting.

Seed stripper: Mechanical harvest when the seeds are ripe. In our experience, a fair amount of seed gets scattered when harvesting with the seed stripper.

Combine/thresher settings: Use rotary flail, holding stalks against the flail until seed is removed.

Seed cleaning: Run through a fanning mill with the following configuration: prescreen 1.8 x 12.7 mm slot; top screen 2.5 x 19 mm slot; bottom screen blank; and with the fan (airflow) on moderate. Run seed through a vacuum separator with high airflow to remove dust and chaff.

Storage requirements: cool dry conditions.

Considerations for Use in Revegetation

Elymus trachycaulus is found growing naturally on coal mine spoils in Alberta, and is tolerant of saline and alkaline soils (*Clements 1910, Strong et al. 1978).

It may perform well on sites with moderate concentrations of boron and bitumen (Hardy 1989).

Elymus trachycaulus ssp. *trachycaulus* slender wheatgrass (continued)

(Considerations for Use in Revegetation, continued)

This species is reported to be somewhat drought tolerant; *Fulbright et al. (1982) report that it requires from 25 to 50 cm of annual precipitation.

Mature plants of *Elymus trachycaulus* can withstand flooding for 49-63 days; seedlings can withstand flooding for 21-35 days. Seeds remain viable after 35-56 days of flooding (**Bolton 1946, **McKenzie 1951, **McKenzie et al.1949).

It is reported to recover rapidly after fire (*Bartos and Mueggler 1982).

Fall sowing appears to have higher germinations rates than spring sowing; surface mulching is recommended (*Brown and Chambers 1990).

Seedlings of this species can be transplanted onto disturbed sites (*Brown et al 1978).

Elymus trachycaulus can be used as a nurse crop with slower growing species (Pahl and Smreciu 1999). Nernberg and Dale (1997) report that under lab conditions it was a good competitor with *Bromus inermis* on dry sites.

Life span of this species is relatively short; it depends on reseeding to perpetuate a stand, but it establishes rapidly from seed (Jefferson and Irvine 1991, Hardy 1989).

Nitrogen fertilizer on dryland sites appears to reduce productivity (Block 2002).

Spring burning is considered detrimental to this species but summer burning is beneficial. (**Namir and Payne 1978).

The seed of *Elymus trachycaulus* is eaten by various seed predators (*Sampson et al. 1951, *Eckert 1975, *Dittberner and Olson 1983).

It is considered a good quality crop species that is fairly palatable (Hardy 1989) and it will maintain vigour indefinitely under moderate grazing (*Sampson et al 1951).

Elymus trachycaulus has good forage for livestock and wildlife but tolerance to grazing is low. It is rated as good in energy value and poor in protein value (*Dittberner and Olson 1983, Hardy 1989).

This species produces natural hybrids with *Elymus glaucus* and other species (*GPFA 1986, *Welsh et al. 1987, and others).

Elymus trachycaulus is widely used for revegetating disturbed land; there are currently cultivars of some subspecies available for reclamation purposes (*Chambers 1989, Darroch and Acharya 1996a).

If restoring northern B.C. ecosystems to resemble natural grasslands found below the alpine tundra, *Elymus trachycaulus* should be a prime candidate for inclusion as a dominant species.

* *fide* Howard 1992.

** *fide* Block 2000.

Notes:_____

Festuca occidentalis Hook.

western fescue **Family: Poaceae**

Figure 36. Documented range of *Festuca occidentalis* in northern British Columbia.

Figure 37. Growth habit of *Festuca occidentalis* in cultivation.

Festuca occidentalis Hook. western fescue (continued)

Background Information

Festuca occidentalis is frequent in both coastal and interior B.C. south of 56° N, is infrequent northwards to 57° N, but is found east to southwest Alberta. It has a disjunct distribution in Ontario and is found south to Michigan, Wisconsin, Wyoming, Utah and California (Douglas et al. 2001).

Growth Form: Tufted bunch grass with a few slender stems, narrow soft basal leaves in tufts, auricles absent, very short ligules (to 0.5 mm), fringed at tips; open fine panicles, drooping at the top (Mackinnon et al. 1992); often with slender black awns, panicle turning white when ripe; mature plant size: 25-70 cm tall. Rooting is often shallow.

Site Preferences: Dry to moist forests and forest openings, rocky slopes at low and middle elevations; found on sides of ruts and old burn piles. In northern B.C. it is reported to be shade tolerant to shade intolerant. Found on xeric to mesic, poor to very rich sites in the SBSx or SBSd subzones, xeric poor to very rich sites in the SBSm subzones; on mesic to subhygric, medium to rich sites in the SBPSx or SBPSd subzones, on submesic to hygric, poor to rich sites in the SBPSmc and on submesic to subhygric poor to rich sites in the SBPSmk (Pavlick 1983, Beaudry et al. 1999). Tolerates a minimum of 355 mm and a maximum of 1143 mm annual precipitation; can tolerate minimum temperatures to -42°C (NRCS 2002).

Seed Information

Seed Size: Length: 3.84 mm (2.30 - 5.69 mm)
Width: 1.30 mm (0.99 - 1.60 mm)
Seeds per gram: 3,058 (range: 2,441 - 3,736)
Volume to Weight Conversion: 168.4 g/L at 87.3% purity
Germination Capacity: At 30°/20° C untreated: 80.8% (55 - 99%)
At 25°/15° C untreated: 89.8% (88 - 91%)
stratified: 59.4% (41 - 78%)
Germination Speed: To first germination: 9.0 days
To 50% potential: 9.8 days
Seed Longevity: Unknown.

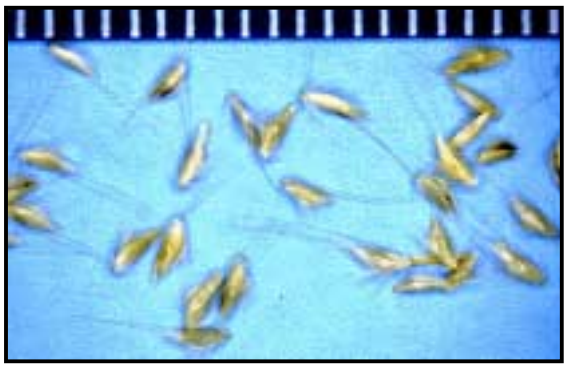

Figure 38. Seeds of *Festuca occidentalis*. Rule divisions are 1.0 mm.

Considerations for Growing

Techniques for Seed Production

Seed treatment: Stratification at 5°C for two months resulted in reduced germination capacity, so no pre-germination seed treatment is recommended.
Soil considerations: Untreated seed germinates best in cooler soils, finely cultivated.
Stand establishment: Loamy firm seedbed recommended; site should be free of all weeds, although grass species can be sprayed with a selective broadleaf herbicide without damage.
Row spacing: Unknown; suggest 40-90 cm.
Seeding density: 131-246 PLS per linear metre.

Festuca occidentalis Hook. western fescue (continued)

(Techniques for Seed Production, continued)

Seeding depth: 0.6-1.2 cm is recommended for *Festuca saximontana* and *F. idahoensis*, but since *F.* occidentalis seeds are smaller, 0.6 cm should be considered a maximum. Early spring seeding is best (Pahl and Smreciu 1999).
Stand maintenance: Regularly cultivate rows and spot spray with herbicide to keep plot weed free; annual fertilization with low N formulations may extend the life of the plot; stand may be rejuvenated by mowing as suggested by Pahl and Smreciu for *F. saximontana.* Plants are nevertheless short-lived, requiring that stands be re-established every three years.

Harvesting and Seed Processing
Dates of selective harvesting in the Bulkley Valley of northwestern B.C. have ranged from July 31st to September 7th. This species shatters moderately easily.
Hand clipping: Harvest manually with a hand sickle or clippers when the seeds are ripe, followed by drying outdoors in the sun, or indoors in a warm dry area.
Vacuum: It is unknown at present if seed can be harvested directly from the stalk with a vacuum. However, since seed shatters relatively easily, we recommend that scattered seed be vacuumed from weed cloth or plastic between rows immediately after any method of harvesting.
Seed stripper: Mechanical harvest with a soft-threaded seed stripper head may be feasible but has not been tested.
Combine/thresher settings: Use rotary flail; hold seed heads against flail until seed is removed.
Seed cleaning: Run through fanning mill twice using the following screens for the first run: prescreen 2.5 x 19 mm slot, top 1.8 x 12.7 mm slot, bottom 1.2 x 7.1 mm slot. The second time through, use a prescreen measuring 1.2 x 7.1 mm slot, a top screen 1.8 x 12.7 mm slot, and a bottom blank.
Storage requirements: Cool dry conditions.

Considerations for Use in Revegetation

Festuca occidentalis has fast reliable germination, with some seed production in the first year. Rapid germination and early growth makes this species a useful component of seed mixtures where rapid green-up and erosion control is required.

Plant longevity is typically only 2-3 years, so longer-lived plants must be included in any revegetation mixture to take their place as they senesce.

Festuca occidentalis is found growing in association with *Pinus contorta, Picea* sp. and *Populus tremuloides* in much of its northern range (Pavlick 1983).

It is possibly a valuable forage grass since *Festuca idahoensis* is considered one of the most palatable forages in the association where it grows (Pavlick 1983, Pahl and Smreciu 1999). *Festuca idahoensis* and *F. occidentalis* are closely related, though *F. occidentalis* is of smaller stature and probably has lower overall productivity even if it has similar palatability.

This species has a high tolerance to drought and fire, and it has low nutrient requirements (NRCS 2002).

Festuca occidentalis Hook. **western fescue**
(continued)

Notes

Festuca saximontana Rydb.
Rocky Mountain fescue **Family: Poaceae**

Figure 39. Documented range of *Festuca saximontana* in northern British Columbia.

Figure 40. Growth habit of *Festuca saximontana* growing in cultivation.

Festuca saximontana Rydb. Rocky Mountain fescue (continued)

Background Information

Festuca saximontana is found north to Alaska, the Yukon and Northwest Territories, east to Newfoundland and south to New York, Michigan, Wisconsin, Iowa, Kansas, New Mexico, Arizona and California. It is common in southern B.C. and east of the Coast-Cascade Mountains, but occurs only infrequently in southwestern and northern B.C. (Douglas et al. 2001).

Growth Form: Small, densely tufted, erect, slender, tightly rolled leaves; auricles absent, very short ligules, finely fringed at tip; narrow panicle looks more like a spike, 3–5 spikelets, short awn 1-2 mm long; Not to be confused with *Festuca rubra* which is rhizomatous and sod-forming. Mature plant size is 25-50 cm tall.

Site Preferences: Mesic to dry meadows and forest openings at middle elevations (Douglas et al. 1994). In northern B.C. it is found on xeric to subxeric poor to very rich sites in the SBSx or SBSd subzones; on submesic to mesic, poor to rich sites in the ESSFx or ESSFd subzones; on xeric very poor to very rich sites in the BWBSw or BWBSv subzones; on xeric to mesic, very poor to very rich sites in the SBPSx or SBPSd subzones, and xeric to subxeric very poor to very rich sites in the SBPSmk (Beaudry et al. 1999). In Alberta, it is reported to grow on dry soils (Gerling et al. 1996).

Seed Information

Seed Size: Length: 3.96 mm (3.27 - 4.85 mm)
Width: 0.91 mm (0.74 - 1.09 mm)
Awn length: 1.63 mm (1.19 - 2.28 mm)

Seeds per gram: 1,500 (range: 531 - 2,130)

Volume to Weight Conversion: 189.2 g/L at 93.6% purity

Germination Capacity: At 30°/20° C untreated: 28.5%
At 25°/15° C untreated: 59.0%
(28 - 97%)
stratified: 20.7%
(10 – 31%)

Germination Speed: To first germination: 11.0 days
To 50% potential: 11.0 days

Seed Longevity: Unknown

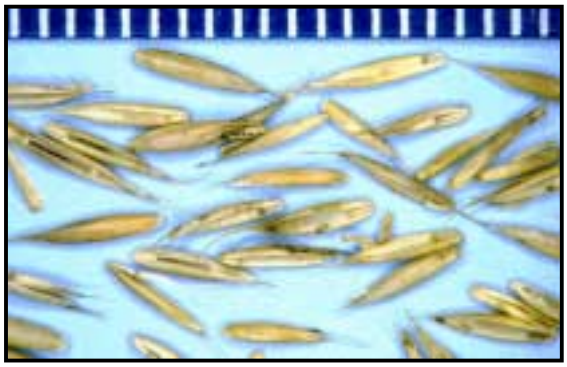

Figure 41. Seeds of *Festuca saximontana*. Rule divisions are 1.0 mm.

Considerations for Growing

Techniques for Seed Production

Seed treatment: Stratification at 5°C for two months has proven detrimental to germination capacity, so no pre-germination seed treatment is recommended.

Soil considerations: Establish on loamy, well-prepared soils with a firm seedbed. Untreated seed germinates better in cooler soils.

Stand establishment: Site should be free of all weeds, although dicot species can be sprayed with a selective broadleaf herbicide with no apparent damage to the crop.

Row spacing: Unknown; suggest 20-50 cm.

Seeding density: 131-246 PLS per linear metre.

Seeding depth: 0.6-1.2 cm; early spring seeding is best (Pahl and Smreciu 1999).

Festuca saximontana Rydb. Rocky Mountain fescue (continued)

(Techniques for Seed Production, continued)

St*and maintenance*: Regularly cultivate rows and spot spray with herbicide to keep plot weed free; annual fertilization with low N formulations may extend the life of the plot. Lightly mowing stands and then removing the straw will rejuvenate them (Pahl and Smreciu 1999).

Harvesting and Seed Processing

Dates of selective harvesting in the Bulkley Valley of northwestern B.C. have ranged from July 17th to August 20th. This species shatters moderately easily.

Hand clipping: Manually harvest with a hand sickle or clippers when seeds are ripe in August, followed by drying outdoors in the sun, or indoors in a warm dry area.

Vacuum: Direct harvesting by vacuum is not recommended. However, plastic placed between rows will enable you to harvest lost seeds that shattered early or were scattered while being harvested by hand clipping or mechanical methods. We recommend that scattered seed be vacuumed from weed cloth immediately after any method of harvesting.

Seed stripper: Should be suitable, but has not been tested; use a soft-threaded harvesting head, then dry harvested seed outdoors in the sun, or indoors in a warm dry area.

Combine/thresher settings: Use rotary flail; hold seed heads against flail till seed is removed.

Seed cleaning: Run through fanning mill with the following configuration: prescreen 1.2 x 7.1 mm slot; top screen 1.8 x 12.7 mm; bottom screen blank.

Storage requirements: Cool dry conditions.

Considerations for Use in Revegetation

Festuca saximontana is suitable for reclamation at high altitudes; and for erosion control on sandy or gravelly soils.

This native fescue has relative large, easy-to-handle seeds, and establishes and grows well under harsh conditions. It can make a robust contribution to the crop portfolio of growers, and to revegetation seed mixtures at most elevations in northern B.C.

This species is eaten by Rocky Mountain bighorn sheep for forage, although forage production is low (Pahl and Smreciu 1999).

Gerling et al. (1996) report that Rocky Mountain fescue has excellent forage value for livestock.

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Festuca saximontana Rydb. (continued) **Rocky Mountain fescue**

Notes

Leymus innovatus (Beal) Pilger
fuzzy-spiked wildrye **Family: Poaceae**

Figure 42. Documented range of *Leymus innovatus* in northern British Columbia.

Figure 43. Growth habit of *Leymus innovatus* growing under cultivation.

Leymus innovatus (Beal) Pilger — fuzzy-spiked wildrye (continued)

Background Information

Douglas et al. (2001b) report that *Leymus innovatus* is infrequently found in northwest and northeast B.C., north to Alaska, the Yukon and Northwest Territories, east to Ontario and south to South Dakota and Wyoming, and that it is found frequently in South Carolina and southeast British Columbia. This species more abundant on the eastern slopes of the Rocky Mountains and is also known as *Elymus innovatus* Beal.

Growth Form: Sod-forming grass, rhizomatous, with a deep-spreading root system; leaves are thin, stiff and inrolled, with well developed auricles, noted for very short ligules; head with a fuzzy stiff spike with short (<3 mm) awns; mature plant size is 50 - 100 cm tall (Hardy 1989, MacKinnon et al. 1992). It reproduces asexually in low light (*Brink et al. 1972, *Campbell and Hinkes 1983, *Densmore and Holmes 1987).

Site Preferences: Open forest, south facing slopes, clearings at low to high elevations in the northern part of the region (MacKinnon et al. 1992); characteristically found on gravelly flats (Hitchcock 1971). In northern B.C., this species is reported to be shade-intolerant to moderately shade-tolerant. It grows on subxeric to submesic, poor to rich sites in the SBSx or SBSd subzones; xeric to subhygric, very poor to very rich sites in the BWBSx or BWBSd subzones; xeric to hygric, very poor to rich sites in the BWBSm subzones, and on subxeric to hygric, poor to rich sites in the BWBSw or BWBSv subzones (Beaudry et al. 1999). Noted as an indicator species of *Pinus* / *Picea glauca* / *Arctostaphylos uva–ursi* association (edaphic climax) on well drained sand dunes in Alberta (Hardy 1989). It is most likely to be found in areas that have been previously burned or disturbed and is most commonly found in lodgepole pine (*Pinus contorta*) forests in association with *Sherpherdia canadensis, Calamagrostis canadensis, Festuca scabrella, Pinus banksiania* and *Picea glauca* (*Hubbard 1969, *Densmore and Holmes 1987, *Gupta et al. 1988 and others).

Seed Information

Seed Size: Length: 12.08 mm (9.92 - 14.30 mm)
Width: 2.87 mm (2.29 - 3.40 mm)

Seeds per gram: 577 (range: 364 - 842)

Volume to Weight Conversion: 54.4 g/L at 81.7% purity

Germination Capacity: At 30°/20° C untreated: 8.3% (7.0% - 9.5%)
At 25°/15° C untreated: 85.3% (73% - 94%)
stratified: 32.3% (12 - 50%)

Germination Speed: To first germination: 12.7 days
To 50% potential: 15.9 days

Seed Longevity: Unknown

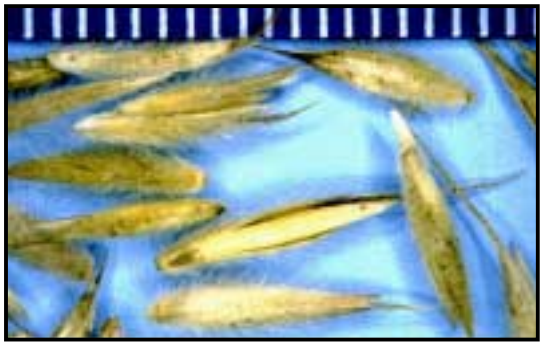

Figure 44. Seeds of *Leymus innovatus*. Rule divisions are 1.0 mm.

Leymus innovatus (Beal) Pilger fuzzy-spiked wildrye (continued)

Considerations for Growing

Techniques for Seed Production

Seed treatment: Seeds stratified at 5°C for two months exhibited poorer germination than untreated seeds, so no pre-germination treatment is recommended.
Soil considerations: Loamy firm seedbed recommended; germinates best in cooler soils.
Stand establishment: Site should be free of all weeds, although dicot species can be sprayed with a selective broadleaf herbicide without damaging the crop plants.
Row spacing: Unknown; suggest 75-120 cm under dryland conditions, 30-90 cm under irrigation.
Seeding density: Unknown at present; suggest 60-100 PLS per linear metre (Smith and Smith 2000).
Seeding depth: 0.6-1 cm, spring or fall seeding.
Stand maintenance: Regularly cultivate rows and spot spray with herbicide to keep plot weed free; annual fertilization with low N formulations will extend the life of the plot.

Harvesting and Seed Processing

Dates of selective harvesting in the Bulkley Valley of northwestern B.C. range from August 25th to October 16th. This species shatters moderately easily.
Hand clipping: Seeds mature from late July to September, depending on site (Ringius and Sims 1997); manual harvest with a hand sickle or clippers is recommended when most seeds are ripe, followed by drying outdoors in the sun, or indoors in a warm dry area.
Vacuum: Direct vaccum harvesting of seeds is not likely to be feasible.
Seed stripper: Seed stripping or swathing can be conducted when more than half of the seeds are ripe. Use a soft-threaded harvesting head with a seed stripper. In our experience a fair amount of seed gets scattered when harvesting with the seed stripper. If using a mechanical stripper, we recommend that seed be vacuumed immediately from weed cloth or plastic placed between rows after harvesting each row.
Combine/thresher settings: Use rotary flail; hold seed heads against rotary flail until seed is removed.
Seed cleaning: Run seed through a fanning mill with the following setup: prescreen 2.5 x 19 mm slot; top screen 4 x 19 mm slot; bottom blank. Then run seed through vacuum separator to remove dust and chaff.
Storage requirements: Cool dry conditions.

Considerations for Use in Revegetation

This species is reported to grow on fine to coarse textured, mesic to dry soils in Alberta (Gerling et al. 1996).

In lab tests, *Leymus innovatus* grew well on sandy soils saturated with various levels of oil, so has potential for rehabilitation of hydrocarbon-contaminated sites (Hardy 1989).

Leymus innovatus is found growing naturally on coal mine spoils in Alberta (Strong et al. 1978) and has been tested for reclamation of such sites in a seed mix with other species (*Fedkenheuer 1979).

Vegetative productivity of this species increased when fertilized with N at levels of 100 kg/ha or more (Seip and Bunnell 1985).

Leymus innovatus is considered effective for erosion control and soil stabilization (Hardy 1989).

Leymus innovatus (Beal) Pilger fuzzy-spiked wildrye (continued)

(Considerations for Use in Revegetation, continued)

Leymus innovatus is considered to have low palatability and nutrition (*Brink et al. 1972; *Chrosciewicz 1978, *Forwood et al. 1985) but in the boreal forest region it provides forage for cattle, and winter forage for mountain sheep in the northern Rockies (MacKinnon et al. 1992). Because of its limited appeal as forage, this species may be suitable for seeding along highways where wildlife is to be discouraged (Hardy 1989).

**fide* Williams 1990.

Notes

Poa alpina L. ssp. *alpina*
alpine bluegrass **Family: Poaceae**

Figure 45. Documented range of *Poa alpina* in northern British Columbia.

Figure 46. Growth habit of *Poa alpina* in cultivation.

Poa alpina L. ssp. *alpina* alpine bluegrass (continued)

Background Information

The natural range of *Poa alpina* is circumboreal. It can be found north to Alaska, the Yukon and Northwest Territories, east to Newfoundland and Nova Scotia, and south to Michigan, Oregon, Colorado, Utah and New Mexico; it is also found in Greenland and Eurasia. Only one subspecies is found in B.C. and it is common throughout the province, especially at higher elevations (Douglas et al. 2001b).

Growth Form: Short tufted bunch grass with mats of basal leaves, short flat wide leaves, ligules 1-3 mm long, no auricles; open broad panicle, lemmas hairy; mature plant size is 5-50 cm tall (MacKinnon et al. 1992).

Site Preferences: Moist to wet meadows, talus slopes and tundra at middle to high elevations (MacKinnon et al. 1992, Douglas et al. 1994). In Alberta it is reported to grow on fine to coarse textured, mesic to dry soils, and to be tolerant of drought and acidic conditions (Gerling et al. 1996). Tolerates a minimum of 610 mm and a maximum of 1398 mm annual precipitation; can tolerate minimum temperatures to -36°C (NRCS 2002).

Seed Information

Seed Size: Length: 4.02 mm (3.43 - 4.57 mm)
Width : 1.38 mm (1.07 - 1.61 mm)
Seeds per gram: 2,931 (range: 2,308 - 3,576)
Volume to Weight Conversion: Unknown
Germination Capacity: At 30°/20° C untreated: 30% (25 - 35%)
stratified: 50.6%.
At 25°/15° C untreated: 80.3% (62 - 98%)
stratified: 67.2% (63 - 72%)
Germination Speed: To first germination: 11.2 days
To 50% potential: 13.3 days
Seed Longevity: Unknown

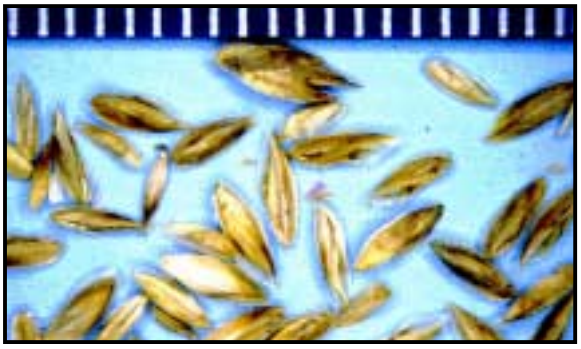

Figure 47. Seeds of *Poa alpina*. Rule divisions are 1.0 mm.

Considerations for Growing

Techniques for Seed Production

Seed treatment: No advantage to two days of cool moist stratification at 5°C when seeds are germinated at 25°/15°, but germination is enhanced after stratification if occurring at warmer temperatures. We generally consider pre-germination not necessary.

Stand establishment: Loamy firm seedbed recommended; site should be free of all weeds, although grass species can be sprayed with a selective broadleaf herbicide without damage; apply phosphorus during establishment and then nitrogen when seedlings are established, annual fertilization with nitrogen yearly thereafter (Smith and Smith 2000).

Row spacing: 20-60 cm; 30 cm is irrigated, 60 cm if dryland (Pahl and Smreciu 1999, Smith and Smith 2000).

Poa alpina L. ssp. *alpina* alpine bluegrass (continued)

(Techniques for Seed Production, continued)

Seeding density: 164-246 PLS per linear metre.
Seeding depth: 0.6 cm; early spring seeding is best (Pahl and Smreciu 1999, Smith and Smith 2000).
Stand maintenance: Regularly cultivate rows and spot spray with herbicide to keep plot weed free. Annual fertilization with low N formulations may extend the life of the plot, and lightly mowing stands then removing the straw will rejuvenate them; mow stands closely immediately after harvesting. This species is best grown under irrigation. Productive stand life of *Poa alpina* is approximately four years, usually with peak seed production in the second or third year (Pahl and Smreciu 1999).

Harvesting and Seed Processing
Dates of selective harvesting in the Bulkley Valley of northwestern B.C. have ranged from July 4th too August 23rd. This species shatters moderately easily.
Hand clipping: Manually harvest with a hand sickle or clippers (some people prefer large scissors) seeds are ripe in July or August, followed by drying in the sun, or indoors in a warm dry area.
Vacuum: It is unlikely that seed of *Poa alpina* can be effectively harvested by direct vacuuming. Like most wild grass species this species shatters when ripe, so plastic placed between rows will enable you to harvest lost seeds that shattered early or were scattered while being harvested by hand clipping or mechanical methods. We recommend that scattered seed be vacuumed from weed cloth immediately after any method of harvesting.
Seed stripper: Moderately effective, especially if crop has ripened uniformly; soft-brushed harvesting head recommended. If harvesting mechanically and seed scatters, use a vacuum to retrieve scattered seed. Dry harvested seed outdoors in the sun, or indoors in a warm dry area.
Combine/thresher settings: 1850 rpm with a 6 mm gap. As seed stalks are relatively short, it is recommended that extra long stalks be left (to hold on to) when planning to use rotary flail for threshing, which works very effectively.
Seed cleaning: Run through fanning mill with the following screens: prescreen 2.1 x 25.4 mm slot; top screen 1.8 x 12.7 mm slot; bottom screen blank.
Storage requirements: Cool dry conditions.

Considerations for Use in Revegetation

Poa alpina has excellent forage value but production is low (Gerling et al. 1996, Pahl and Smreciu 1999).

A low-statured perennial grass species, *Poa alpina* is an important species for high altitude reclamation (Hardy, 1989, Pahl and Smreciu 1999).

Tolerance of a wide range of climatic and soil conditions makes this a very flexible species, for use in revegetation; germinates reliably in the field, and is longer lived than *Festuca occidentalis*.

Some cultivated varieties are now registered, generally derived from single alpine populations (e.g., from the Rocky Mountains of Alberta); see Darroch and Acharya (1996b).

Poa alpina has a high tolerance to fire and medium tolerance to drought with low nutrient requirements (NRCS 2002).

Poa alpina* L. ssp. *alpina **alpine bluegrass**
(continued)

Notes

Trisetum spicatum (L). Richt.

spike trisetum **Family: Poaceae**

Figure 48. Documented range of *Trisetum spicatum* in northern British Columbia.

Figure 49. Growth habit of *Trisetum spicatum* in cultivation.

Trisetum spicatum (L). Richt. spike trisetum (continued)

Background Information

Trisetum spicatum has a circumpolar distribution, found north to Alaska, the Yukon and Northwest Territories, east to Newfoundland and south to Virginia, Tennessee, Minnesota, South Dakota, New Mexico, Arizona, California and Mexico, and is also found throughout Eurasia and South America. It is common throughout B.C., although is less frequent along the coast (Douglas et al. 2001b).

Growth Form: Long-lived densely tufted bunchgrass; flat lax leaves with thin tips, no auricles, ligules 0.5-2 mm long; inflorescence is a dense spike-like panicle 5 to 15 cm long, lemma has a distinctive long bent awn from near the middle; mature plant size is 10-50 cm long (Hardy 1989, MacKinnon et al. 1992).

Site Preferences: Usually found on dry, often rocky sites, but occasionally in moist areas, dry open forests and alpine tundra, found at low to high elevations (Hardy 1989, MacKinnon et al. 1992).
In northern B.C., this species is reported to vary from shade-tolerant to light-demanding and to be commonly found in openings and open forests. It is found on xeric to subxeric, poor to rich sites in the SBSx, SBSd, and SBSm subzones; on xeric to subxeric, poor to rich sites in the ESSFx or ESSFd subzones; on xeric to mesic, very poor to medium sites in the SBPSx or SBPSd subzones; on xeric, very poor to poor sites in the SBPSmc, and on xeric to submesic, poor to medium sites in the SBPSwk (Beaudry et al. 1999). It tolerates a minimum of 305 mm and a maximum of 1270 mm annual precipitation; can tolerate minimum temperatures to -39°C (NRCS 2002).

Seed Information

Seed Size: Length: 2.03 mm (1.64 - 2.44 mm)
Width: 0.98 mm (0.81 - 1.17 mm)
Seeds per gram: 5,622 (range: 5,000 - 6,352)
Volume to Weight Conversion: 51.3 g/L at 82.5% purity
Germination Capacity: At 30°/20° C untreated: 64.3% (60 - 68%)
At 25°/15° C untreated: 52.7% (5 -79%)
stratified: 26.0% (7 - 45%)
Germination Speed: To first germination: 10.1 days.
To 50% potential: 10.4 days.
Seed Longevity: Unknown

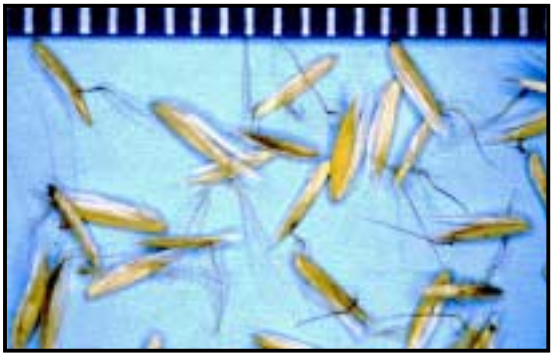

Figure 50. Seeds of *Trisetum spicatum*. Rule divisions are 1.0 mm.

Considerations for Growing

Techniques for Seed Production

Seed treatment: Two months stratification at 5°C resulted in germination capacity cut in half, so no germination pre-treatment is recommended.
Stand establishment: Loamy firm seedbed recommended; untreated seed germinates best in warm soils; site should be free of all weeds, although grass species can be sprayed with a selective broadleaf herbicide without damage.

Trisetum spicatum (L). Richt. spike trisetum (continued)

(Techniques for Seed Production, continued)
Row spacing: Unknown; suggest 75-120 cm under dryland conditions, 30-90 cm under irrigation.
Seeding density: Unknown at present; suggest 60-100 PLS per linear metre.
Seeding depth: 1.3-2.5 cm (Smith and Smith 2000).
Stand maintenance: Regularly cultivate rows and spot spray with herbicide to keep plot weed free; wild stands are long-lived even on poor sites, so fertilization an annual basis should be done sparingly, and with a low nitrogen formulation.

Harvesting and Seed Processing
Dates of selective harvesting in the Bulkley Valley of northwestern B.C. have ranged from July 11th to August 15th. This species shatters moderately easily.
Hand clipping: Harvest manually with a hand sickle or clippers when seeds are ripe in late July or early August, followed by drying outdoors in the sun, or indoors in a warm dry area.
Vacuum: It is unknown at present if seed can be harvested directly from the stock with a vacuum. Like all wild grass species this species shatters when ripe; plastic placed between rows will enable you to harvest lost seeds that shattered early or were scattered while being harvested by hand clipping or mechanical methods. We recommend that scattered seed be vacuumed from weed cloth immediately after any method of harvesting.
Seed stripper: This species may be harvested with a seed stripper having a soft-threaded harvesting head. If harvesting mechanically and seed scatters, use a vacuum to retrieve scattered seed. Dry harvested seed outdoors in the sun, or indoors in a warm dry area.
Combine/thresher settings: 1850 rpm with a 1 - 2 mm gap. Rotary flail works best if harvested with long stalks.
Seed cleaning: Run through fanning mill with the following configuration: prescreen 1.2 x 7.1 mm slot; top screen 1.8 x 12.7 mm slot; bottom screen blank.

Considerations for Use in Revegetation

In Alberta, *Trisetum spicatum* is reported to grow on coarse textured mesic to dry soils and to be tolerant of drought, acidic and alkaline conditions (Gerling et al. 1996).

According to NRCS (2002), this species has a high tolerance to fire and medium tolerance to drought, with low nutrient requirements. Hardy (1989) reports that it is moderately to extremely drought tolerant (Hardy 1989).

This is a pioneer species on calcareous talus slopes, so probably has low nutrient requirements and tolerance of mildly alkaline to mildly acidic conditions (Hardy 1989).

Trisetum spicatum has a high root:shoot ratio and may be useful, therefore, for soil building and erosion control (Hardy 1989).

This is a useful species in revegetation mixtures where a medium-statured, long-lived grass is desired, especially in high-altitude and high-latitude environments.

NRCS (2002) report that it has high palatability to both browsing and grazing animals, with protein content rated as medium.

Trisetum spicatum is an important forage plant for wildlife in the subalpine and alpine zones throughout the growing season and late in the fall (Stubbendieck et al. 1982, MacKinnon et al. 1992, Hardy 1989, Gerling et al. 1996).

Trisetum spicatum (L). Richt. spike trisetum (continued)

Notes

Sedges and Rushes

Carex aenea Fern.

bronze sedge **Family: Cyperaceae**

Figure 51. Documented range of *Carex aenea* in northern British Columbia.

Figure 52. Growth habit of *Carex aenea* in cultivation.

Carex aenea Fern. bronze sedge (continued)

Background Information

Carex aenea is found north to Alaska and the Yukon, east to Newfoundland and Labrador, and south to Massachusetts, Pennsylvania, Minnesota, South Carolina, Montana, Idaho and Washington (Douglas et al. 2001a). In B.C. it is commonly found in, and east of, the Coast-Cascade Mountains on dry disturbed sites and open forests in the lowland and montane zones and is infrequently found in coastal southwestern B.C. (FEIS various dates). It is reported by MacKinnon et al. (1992) to be common throughout the northern Interior of B.C.

Growth Form: Dense tufts on slender wiry stems, bent over at the tip; 4-8 sessile spikes in a loose awned cluster, lower spikes well separated, bronze perigynia; soft flat leaves 2-4 mm wide; mature plant size is up to 100 cm tall (MacKinnon et al. 1992, Douglas et al. 1994). Flower colour is greenish brown; fruit colour is yellow-brown. Can be confused with *Carex praticola* (Roberts 1983).

Site Preferences: In northern British Columbia, this species is found in dry to moist open forests, on forest edges, in meadows and clearings at low to middle elevations. It often grows in profusion on disturbed sites (MacKinnon et al. 1992).

Seed Information

Seed Size: Length: 4.33 mm (3.92 - 4.78 mm)
Width : 1.81 mm (1.45 - 2.11 mm)

Seeds per gram: 1,399 (range: 1,136 – 1,853)

Volume to Weight Conversion: 398.2 g/L at 93.3% purity

Germination Capacity: At 30°/20° C untreated: 72.9%
(63 - 81%)
stratified: 87.8%
At 25°/15° C untreated: 64.2%
(61 - 68%)
stratified: 54.2%
(48 - 61%)

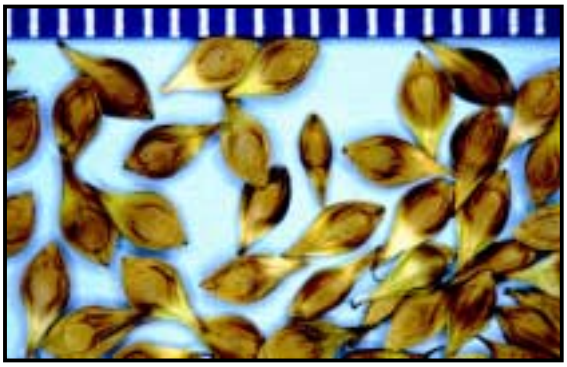

Figure 53. Seed of *Carex aenea*. Rule divisions are 1.0 mm.

Germination Speed: To first germination: 37.0 days
To 50% potential: 47.0 days

Seed Longevity: In our research, seeds of *Carex aenea* had 10% lower germination after storage under cool dry conditions for two years.

Considerations for Growing

Techniques for Seed Production

Seed treatment: Germinates best in warm soils, where stratification also seems beneficial.

Soil considerations: Establish on loamy, well prepared soils with a firm seedbed. Germination tests suggest superior germination under warm (almost hot) conditions.

Stand establishment: Site should be free of all weeds, especially rhizomatous grasses and other persistent species, to limit competition. This species may have complex dormancy requirements, so fall seeding is recommended, and it may still take two to three years to establish plots successfully from seed. Symbios Research and other researchers (Smith and Smith 2000) found propagation from greenhouse-grown plugs to be more effective for all *Carex* spp.

Carex aenea Fern. bronze sedge (continued)

(Techniques for Seed Production, continued)

Row spacing: Unknown; suggest 75-120 cm under dryland conditions, 30-90 cm under irrigation.
Seeding density: Unknown at present; suggest 60-100 PLS per linear metre (Smith and Smith 2000).
Seeding depth: 0.6-1.2 cm.
Stand maintenance: Regularly cultivate rows and spot spray with herbicide to keep plot weed free. Our *Carex aenea* plot was sprayed with the selective broadleaf herbicide Banvel™ (active ingredient, dicamba) to control weeds. It survived the spraying but there appeared to be reduced seed set that year. Annual fertilization with low N formulations may extend the life of the plot.

Harvesting and Seed Processing
Dates of selective harvesting in the Bulkley Valley of northwestern B.C. have ranged from August 22nd to October 9th. This species shatters moderately easily.
Hand clipping: Have hand tools very sharp (hand clippers or hand sickles) because seed stalks are hard and movement of the seed heads easily dislodges seed. Hold the seed heads over bins placed alongside the plants being clipped, or place a bag over the seed heads before clipping to minimize seed loss.
Vacuum: Suitability unknown.
Seed stripper: Suitability unknown.
For both hand clipping and mechanical harvesting, laying plastic between rows is recommended so any scattered seeds can be salvaged by sweeping or vacuuming.
Combine/thresher settings: Run at 1850 rpm with 6 mm gap; rotary flail machine works best if seed heads are harvested with long stalks.
Seed cleaning: After thrashing, put through fanning mill with the following screen configurations: prescreen 1.8 x 12.7 mm slot; top screen 1.2 x 7.1 mm slot; bottom screen blank. Then use vacuum separator with speed and suction set to medium to remove dust and <5% of seeds.
Storage requirements: Cool dry conditions, though seeds of this species appear especially tolerant of a wide range of environmental conditions.

Considerations for Use in Revegetation

Carex aenea is slow to establish but often grows in profusion on very disturbed sites (MacKinnon et al. 1992, Haeussler et al. 2002).

Carex aenea exhibited poorer emergence than *C. macloviana* in most field trials, and its inclusion in seed mixtures can be considered an investment in long-term inoculation of the site's seed bank.

This species is suitable for establishment on upland sites, especially those dominated by clayey or compacted soils.

Some *Carex* species are moderately grazed by wildlife, though palatability is generally considered lower than most grasses (Hardy 1989).

Some *Carex* species are said to have extensive root systems so are suitable for erosion control Hardy 1989); whether *Carex aenea* has such a root system needs to be verified.

Carex aenea Fern. (continued) **bronze sedge**

Notes

Carex macloviana d'Urv.
Falkland Island sedge **Family: Cyperaceae**

Figure 54. Documented range of *Carex macloviana* in northern British Columbia.

Figure 55. Growth habit of *Carex macloviana* in cultivation.

Carex macloviana d'Urv. — Falkland Island sedge (continued)

Background Information

Carex macloviana is a disjunct circumpolar species found north to Alaska, the Yukon and Northwest Territories, with isolated populations found in Labrador, Wyoming and Colorado, Greenland, Iceland, northern Europe, and even in the southern hemisphere in southern Chile and the Falkland Islands. It is reportedly frequent in northern British Columbia but rare in southern B.C and east of the Coast-Cascade Mountains (Douglas et al. 2001a).

Growth Form: Densely tufted with short rhizomes; sessile spikes crowded into a dense head; copper coloured to olive green perigynia; short flat leaves, 2-4 mm wide, much shorter than stem; mature plant size: 20 - 50 cm tall (MacKinnon et al. 1992).

Site Preferences: Dry to moist open forests, thickets, meadows, grassy slopes, lakeshores, clearings, and peatlands from low to high elevations throughout the northern Interior of B.C. (MacKinnon et al. 1992, Douglas et al. 1994).

Seed Information

Seed Size: Length: 3.56 mm (3.01 - 4.11 mm)
Width: 1.48 mm (1.12 - 1.89 mm

Seeds per gram: 1,991 (range: 1,424 - 2,514)

Volume to Weight Conversion: 232.4 g/L at 87.0% purity

Germination Capacity: At 30°/20° C untreated: 66.1%
(61.3 - 75.5%)
stratified: 49.8%
At 25°/15° C untreated: 69.7%
stratified 70.0%

Germination Speed: To first germination: 25.0 days
To 50% potential: 41.5 days

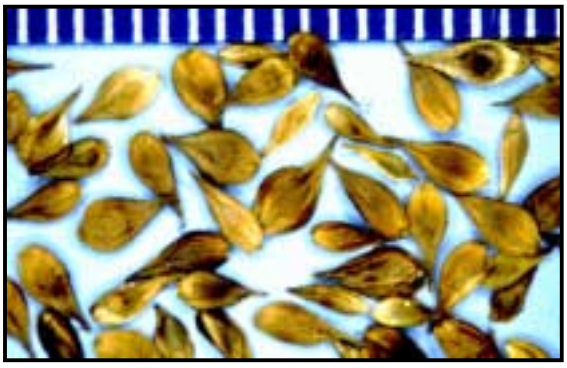

Figure 56. Seeds of *Carex macloviana*. Rule divisions are 1.0 mm.

Seed Longevity: Link (1993) reports that two similar species (*Carex microptera* and *Carex pachystachya*) may be stored for two to many years because the hull apparently contains germination inhibitors. In our research, although two year old seeds were still viable, germination rates were beginning to decline.

Considerations for Growing

Techniques for Seed Production

Seed treatment: Stratification was not beneficial in our germination tests. For *Carex microptera*, Link (1993) suggests a 60 day soak under dark conditions.

Soil considerations: Establish on loamy, well-prepared soils, with a firm seedbed.

Stand establishment: Site should be free of all weeds. Little is known about stand establishment from seed; this species may have complex dormancy requirements, so fall seeding is recommended, and it may take two to three years to establish plots successfully from seed. As recommended by Smith and Smith (2000), we have found propagation from greenhouse-grown seedlings to be more quickly successful for all *Carex* spp.

Carex macloviana d'Urv. Falkland Island sedge (continued)

(Techniques for Seed Production, continued)

Row spacing: Unknown; suggest 75 to 120 cm under dryland conditions, 30 to 90 cm with good irrigation.
Seeding density: Unknown at present; suggest 60-100 PLS seeds per linear metre (Smith and Smith 2000).
Seeding depth: 0.6-1.2 cm.
Stand maintenance: Regularly cultivate rows and spot spray with herbicide to keep plot weed free. Our *Carex macloloviana* plot was sprayed with the selective broadleaf herbicide Banvel™ to control dicot weeds. It survived the spraying but there appeared to be reduced seed set that year. Annual fertilization with low N formulations may extend the life of the plot.

Harvesting and Seed Processing
Dates of selective harvesting in the Bulkley Valley of northwestern B.C. range from August 21st to October 18th. Timing of harvest is important as seed scatters moderately easily.
Hand clipping: Have hand tools (hand clippers or hand sickles) very sharp because movement of the seed heads easily dislodges seed and they can be lost, and seed stalks are moderately hard. Hold the seed heads over bins placed alongside the plants being clipped or place a bag over the seed heads before clipping to minimize seed loss.
Vacuum: Suitability unknown.
Seed stripper: Possibly suitable. Because the seeds shatter easily, if you are using mechanical harvesting methods, plastic between rows is recommended so the many scattered seeds can be salvaged by sweeping or vacuuming.
Combine/thresher settings: Run at 1548 rpm with 4 mm gap; seed stalks are usually not long enough to safely use with the rotary flail.
Seed cleaning: After threshing, run through a fanning mill twice. For the first run, use the following screen configuration: prescreen 4.89 mm round; top screen 2.83 mm square; bottom screen 0.5 mm square. For the second run, use these screens: prescreen 2.36 mm square; top screen 2.83 mm square; bottom screen 0.5 mm square. Then use a vacuum separator with speed and suction set to medium to remove dust and <5% of seeds.
Storage requirements: Cool dry conditions; for *Carex microptera*, Link (1993) suggests 0.6–7.2° C as the optimum temperature range for seed storage.

Considerations for Use in Revegetation

Carex macloviana germinates more quickly than *Carex aenea* in lab tests, and has also shown better emergence in field trials.

This species is reported to grow on wet to mesic soils in Alberta (Gerling et al. 1996).

Some *Carex* species are moderately grazed by wildlife, though palatability is generally lower than that of most grasses (Hardy 1989).

Some *Carex* species are said to have extensive root systems so are suitable for erosion control Hardy 1989); whether *Carex macloviana* has such a root system needs to be verified.

This species may take two to three years to establish.

Carex macloviana d'Urv. Falkland Island sedge (continued)

(Considerations for Use in Revegetation, continued)

Carex macloviana is suitable for growth on upland sites, especially those with compacted or clayey soils.

Notes

Carex mertensii Prescott in Bong.

Mertens' sedge **Family: Cyperaceae**

Figure 57. Documented range of *Carex mertensii* in northern British Columbia.

Figure 58. Growth habit of *Carex mertensii* in cultivation.

Carex mertensii Prescott in Bong. Mertens' sedge (continued)

Background Information

Carex mertensii is found in wet places north to Alaska and the southern Yukon, east to Alberta and south to Idaho, Montana and California, and is also found in eastern Asia. It is commonly found in moist lowland and montane zones in B.C. south of 55°N and rarely in northwest B.C. (Hitchcock et al. 1969, Douglas et al. 2001a).

Growth Form: Slender stalks; densely tufted, with cylindrical spikes crowded together and drooping distinctively; white oval papery flattened perigynia; short flat leaves 4 -7 mm wide; mature plant size up to 120 cm tall (MacKinnon et al. 1992, Douglas et al. 1994).

Site Preferences: Moist to wet forest openings, rocky slopes, disturbed areas, roadsides, and ditches at middle to high elevations (not alpine) in the south half of the northern Interior (MacKinnon et al. 1992, Douglas et al. 1994). Under coastal conditions, it is reported to occur on fresh to very moist nitrogen rich soils, often near streams or on seepage sites, characteristic of disturbed sites on high elevation clearcuts and roadsides (Klinka et al. 1989).

Seed Information

Distinctive flat, papery tan coloured seeds.

Seed Size: Length: 4.62 mm (4.10 - 5.14 mm)
Width: 2.85 mm (2.48 - 3.34 mm)
Thickness: 0.67 mm (0.23 - 0.98 mm)

Seeds per gram: 1,555 (range: 1,551 - 2,212)

Volume to Weight Conversion: 108.5 g/L at 91.1% purity

Germination Capacity: At 30°/20° C untreated: 68.5% (37 - 93%)
At 25°/15° C untreated: 32.7% (32 - 33%)
stratified: 87.2% (84 - 90%)

Germination Speed: To first germination: 22.9 days
To 50% potential: 37.5 days

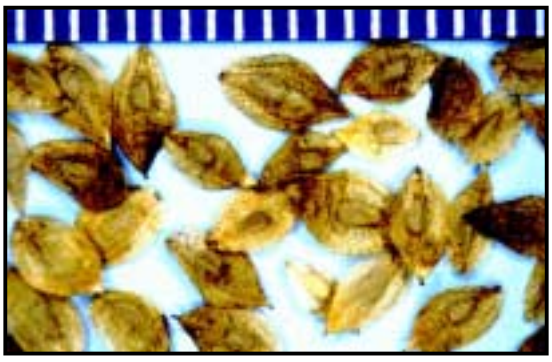

Figure 59. Seeds of *Carex mertensii*. Rule divisions are 1.0 mm.

Seed Longevity: In our research, seeds of *Carex mertensii* retained their viability after storage under cool dry conditions for two years.

Considerations for Growing

Techniques for Seed Production

Seed treatment: Responds well to stratification at lower soil temperatures; adequate germination of untreated seeds at higher temperatures as well.

Soil considerations: Establish on loamy, well prepared soils, with a firm seedbed; may prefer slightly cooler conditions.

Stand establishment: Site should be free of all weeds. Little is known about stand establishment from seed; this species may have complex dormancy requirements, so fall seeding is recommended.

Carex mertensii Prescott in Bong. Mertens' sedge (continued)

(Techniques for Seed Production, *Stand establishment*, continued)

We have found greenhouse propagation of all *Carex* spp. seedlings, followed by outplanting of plugs, to the most effective means of establishing seed increase plots and small seed production fields, as also recommended by Smith and Smith (2000).
Row spacing: Unknown; suggest 75 to 120 cm under dryland conditions, 30 to 90 cm with good irrigation.
Seeding density: Unknown at present; suggest 60-100 PLS seeds per linear metre (Smith and Smith 2000).
Seeding depth: 0.6-1.2 cm.
Stand maintenance: Regularly cultivate rows and spot spray with herbicide to keep plot weed free. Our *Carex mertensii* plot was sprayed with the selective broadleaf herbicide Banvel™ (dicamba active ingredient) to control weeds without damage to plant growth, and with no apparent impact on seed yield. Annual fertilization with low N formulations may extend the life of the plot. Apparently rust can sometimes infect the leaves in early to middle spring or in late summer, but can be controlled in established fields with application of Tilt™ fungicide (Link 1993).

Harvesting and Seed Processing
Dates of selective harvesting in the Bulkley Valley of northwestern B.C. range from September 3rd to October 1st. Timing of harvest is important as this seed shatters easily when it is ripe.
Hand clipping: Have hand tools (hand clippers or hand sickles) very sharp because movement of the seed heads easily dislodges seed, and seed stalks are very thick and rigid. Hold the seed heads over bins placed alongside the plants being clipped or place a bag over the seed heads before clipping to minimize seed loss.
Vacuum: Suitability unknown but unlikely, as seeds that are ripe enough to be sucked up are just as likely to fall to the ground first.
Seed stripper: Unknown suitability, but since the seeds shatter easily, only a gently brushing harvesting head could be used. If you are using any mechanical harvesting method, laying plastic between rows is recommended so the scattered seeds can be salvaged by sweeping or vacuuming.
Combine/thresher settings: Hold stalks and put seed heads into a rotary flail.
Seed cleaning: Put through fanning mill two times after threshing. For the first run, screen configurations should be as follows: prescreen 4 x 19 mm slot; top screen 2.5 x 19 mm slot; bottom screen 1.8 x 12.7 mm. For the second run, use a prescreen with a 1.8 x 12.7 mm slot, followed by a top screen measuring 2.5 x 19 mm in a slot shape, and leave the bottom blank. Then use a vacuum separator with speed and suction set to low to remove dust and <5% of seeds.
Storage requirements: Cool dry conditions (Link 1993).

Considerations for Use in Revegetation

Carex mertensii germinates more quickly than *Carex aenea* and *Carex macloviana* in lab tests.
Hermann (1970) reports that *Carex mertensii* is grazed by livestock. Hardy (1989) reports that other *Carex* species are moderately grazed by wildlife, though are generally less palatable than most grasses.

Carex mertensii Prescott in Bong. (continued) — Mertens' sedge

(Considerations for Use in Revegetation, continued)

This species is well suited for revegetating seepage areas and moist meadows, especially at higher elevations, but should not be considered an "aquatic sedge" that can persist in marshes or fens with long-standing surface waters.

Some *Carex* species are said to have extensive root systems so are suitable for erosion control (Hardy 1989); whether *Carex mertensii* has such a root system needs to be verified.

Other considerations

The attractive drooping heads and lush foliage of this species make it aesthetically pleasing, and possibly of horticultural value as an ornamental species.

Notes

Luzula parviflora (Ehrh.) Desv.
small-flowered wood-rush **Family: Juncaceae**

Figure 60. Documented range of *Luzula parviflora* in northern British Columbia.

Figure 61. Growth habit of *Luzula parviflora* in cultivation.

Luzula parviflora (Ehrh.) Desv. small-flowered wood-rush (continued)

Background Information

Luzula parviflora is a circumpolar species found north to Alaska, the Yukon and the Northwest Territories, east to Newfoundland, south to New York, Michigan, Wyoming and California, and is also found in Eurasia and Greenland. In British Columiba, it is found on wet to mesic soils in moist open forests and marshy areas in boreal and subalpine forests and above treeline (Gerling et al. 1996, Douglas et al. 2001a).

Growth Form: Rhizomatous on solitary stems, reddish at base; large yellowish green basal leaves, 12-17 cm long, 5-10 mm wide (Hämet-Ahti 1971); single or paired flowers with open nodding panicle; mature plant size 20-80 cm high (MacKinnon et al. 1992, Douglas et al. 1994).

Site Preferences: Fairly nutrient rich, mesic to moist alluvial forests, thickets, and meadows at low to high elevations (Hämet-Ahti, 1971, MacKinnon et al. 1992, Douglas et al. 1994). In coastal B.C. reported to be shade tolerant/intolerant, occurring on fresh to very moist nitrogen-medium soils. Less abundant on water-shedding and water-receiving sites, and is characteristic of friable mor and acidic modor humus forms (Klinka et al. 1989). *Luzula parviflora* is reported by Gerling et al. (1996) to grow in cool valley bottoms on mesic to sub-hygric sites in Alberta's upper foothills, where temperatures are cool and average annual precipitation is near 540 mm (340 mm of which falls in the summer).

Seed Information

Seed Size: Length: 1.02 mm (.085 - 1.19 mm)
Width: 0.60 mm (0.49 - 0.76 mm)
Seeds per gram: 6,241 (range: 4,254 - 8,591)
Volume to Weight Conversion: Unknown
Germination Capacity: At 30°/20° C untreated: 74.8% (53 – 97%)
stratified: 58.0%
At 25°/15° C untreated: 92.0%
stratified: 79.0%
Germination Speed: To first germination: 25.0 days
To 50% potential: 42.1 days
Seed Longevity: Unknown.

Figure 62. Seeds of *Luzula parviflora*. Rule divisions are 1.0 mm.

Considerations for Growing

Techniques for Seed Production

Seed treatment: Stratification for two months at 5°C appears to have reduced germination capacity, at least when tested at 25°/15°C, so no pre-germination treatment is recommended.

Soil considerations: Establish on loamy, well prepared, soils with a firm seedbed; germinates best in cool soils.

Stand establishment: Site should be free of all weeds. Our *Luzula parviflora* plot was sprayed with the selective broadleaf herbicide Banvel™ (active ingredient dicamba) to control weeds with no apparent damage to plant growth. Little is known about stand establishment from seed.

Luzula parviflora (Ehrh.) Desv. small-flowered wood-rush (continued)

(Techniques for Seed Production, *Stand establishment* continued)

Our seed production plots were successfully established by propagating seedlings from seed in containers in a greenhouse, with plugs then transplanted to the field.
Row spacing: Unknown; suggest 75 to 120 cm under dryland conditions, 30 to 90 cm with good irrigation.
Seeding density: Unknown at present; suggest 60-100 PLS seeds per linear metre (Smith and Smith 2000).
Seeding depth: Shallow.
Stand maintenance: Regularly cultivate rows and spot spray with herbicide to keep plot weed free; annual fertilization with low N formulations may extend the life of the plot.

Harvesting and Seed Processing
Date of first harvesting in the Bulkley Valley of northwestern B.C. has been as early as July 17th. This species shatters moderately easily.
Hand clipping: Use sharp hand clippers. Hold the seed heads over bins placed alongside the plants being clipped or place a bag over the seed heads before clipping to minimize seed loss.
Vacuum: Suitability unknown (not likely).
Seed stripper: It is unknown how well mechanical harvesting methods will work, but since the seed heads do not easily shatter and the seeds are hard, this species may be a good candidate for such methods.
Combine/thresher settings: Run at 1548 rpm with 4 mm gap.
Seed cleaning: Put through fanning mill with the following screen sizes: prescreen 1.2 mm x 7.1 mm slot; top screen 1.2 mm x 1.5 mm slot ; bottom blank. Then do a final cleaning using a 0.6 mm hand sieve.
Storage requirements: Cool dry conditions.

Considerations for Use in Revegetation

In Alberta, *Luzula parviflora* is reported to grow on medium to coarse wet to mesic soils (Gerling et al. 1996).

Economical basal leaves, and ability to grow on poor soils, make this species a useful contribution to revegetation mixes at all elevations.

Luzula parviflora provides excellent forage value (Gerling et al. 1996).

Other considerations

Luzula parviflora is an attractive little plant with possible value as an ornamental.

***Luzula parviflora* (Ehrh.) Desv.** **small-flowered wood-rush (continued)**

Notes

Legumes

Lathyrus ochroleucus Hook.

creamy peavine **Family: Fabaceae**

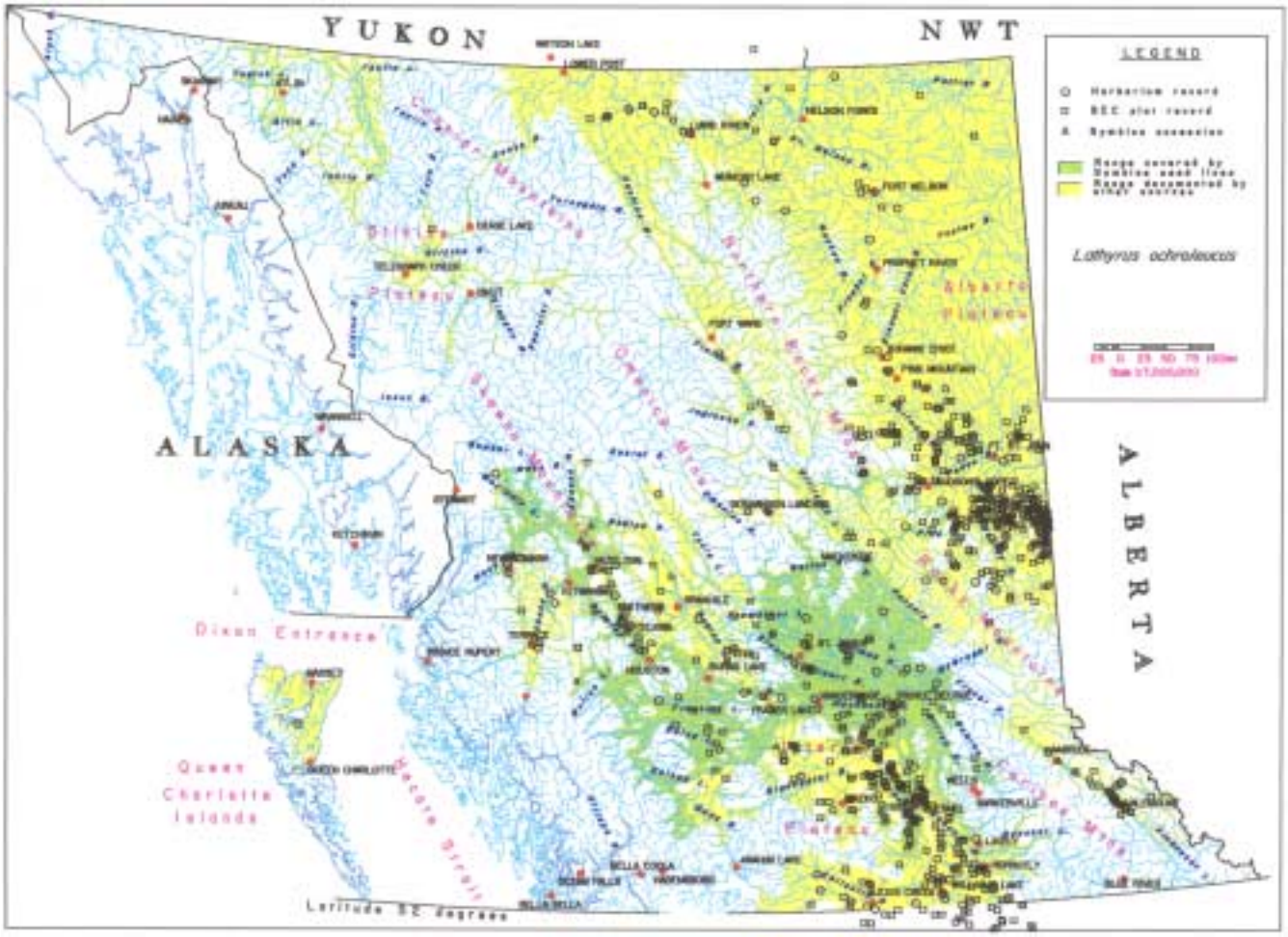

Figure 63. Documented range of *Lathyrus ochroleucus* in northern British Columbia.

Figure 64. Growth habit of *Lathyrus ochroleucus* when grown in the open, under cultivation.

Lathyrus ochroleucus Hook. creamy peavine (continued)

Background Information

Lathyrus ochroleucus is found north to the Northwest Territories, east to Quebec and south to Ohio, Pennsylvania, Vermont, South Dakota, Wyoming, Nebraska and Washington (Douglas et al. 1999a). In B.C. it is found in continental boreal and wet cool temperate climates on moderately dry to fresh nitrogen-rich soils in the Interior. On the Coast, it increases with increasing continentality and decreases with increasing elevation. It is common in semi-open mesic forests on rich water-shedding and water receiving sites in the lowland and montane zones (Klinka et al. 1989).

Growth Form: Nitrogen-fixing rhizomatous herb (forms symbiotic root nodules with *Rhizobium* bacteria), with erect to clambering slightly angled stems; alternate leaves with 6 - 8 leaflets in pairs, grasping broad stipules, one end rounded; loose cluster of 6 - 14 pea-like whitish flowers; mature plant size is 30 - 100 cm tall (MacKinnon et al. 1992, Douglas et al. 1999a).

Site Preferences: Mesic to moist open forests, thickets, glades meadows and rocky ridges, usually at low to middle elevations in the southern half of the region (MacKinnon et al. 1992, Douglas et al. 1999a); characteristic of moder and mull humus forms (Klinka et al. 1989); frequently found under trembling aspen (*Populus tremuloides*). In northern B.C., *Lathyrus ochroleucus* is reported to be shade-tolerant to shade-intolerant, to be abundant in mesic and near mesic deciduous nature seral forests. It is widely distributed in the SBS where SMR <5 and the SNR falls between B and E, though is more narrowly distributed in the SBSmc (SMR 2-5). It is found on wet or very wet fertile sites in the SBPSmk (SMR 2-5), and is less common on fertile dry sites in the SBPS. This species is found on moist, wet and very wet sites in the BWBS (SMR 2-5; Beaudry et al. 1999). *Laythrus ochroleucus* is considered diagnostic of the mw subzone of the BWBS (DeLong et al. 1991).

Seed Information

Seed Size: Length: 3.20 mm (2.66 - 3.72 mm)
Width: 2.77 mm (2.48 - 3.05 mm)

Seeds per gram: 61 (range: 59 - 62)

Volume to Weight Conversion: Unknown

Germination Capacity: At 30°/20° C,
scarified/stratified: 13.8%
At 25°/15° C untreated: 21.0%
stratified: 27.3%

Germination Speed: To first germination: 18 days
To 50% potential: 18 days

Seed Longevity: Reported to remain in the seedbank for many years until dormancy is broken (*Tannas 1997).

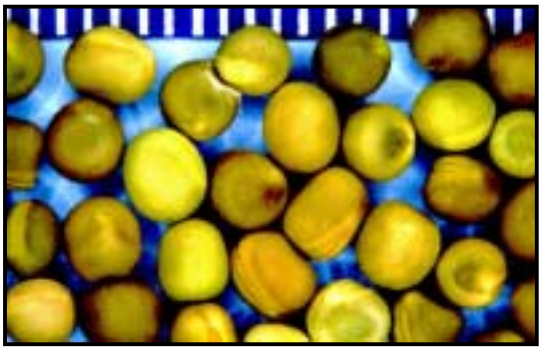

Figure 65. Seeds of *Lathyrus ochroleucus*. Rule divisions are 1.0 mm.

Considerations for Growing

Techniques for Seed Production

Seed treatment: Stratification or scarification (scoring or cracking the seed coat) is slightly beneficial, at least at cooler temperatures.

Soil considerations: Prefers loam to sandy loam (Hardy 1989), with a well-prepared firm seedbed. Germinated better under cool conditions.

Lathyrus ochroleucus Hook. creamy peavine (continued)

(Techniques for Seed Production, continued)

Stand establishment: Fall planting may be preferable to allow winter stratification assist in breaking seed dormancy. Site should be free of all weeds, especially rhizomatous grasses and other persistent species because there are currently no selective herbicides that can be used once plants are growing.
Row spacing: Unknown; suggest 75 to 120 cm under dryland conditions, 30 to 90 cm with good irrigation.
Seeding density: Unknown at present; suggest 60-100 PLS seeds per linear metre (Smith and Smith 2000).
Seeding depth: 1 cm (Pahl and Smreciu 1999).
Stand maintenance: Regularly cultivate rows and spot spray with herbicide to keep plot weed free; annual fertilization with high P, high K, and low N formulations may extend the life of the plot.

Harvesting and Seed Processing
Dates of selective harvesting in the Bulkley Valley of northwestern B.C. range from August 5th to as late as October 1st. Timing of harvest is important as pods dehisce easily when seeds are ripe.
Hand clipping: Use sharp hand clippers. Harvest pods as they turn light brown. Hold the seedpods over bins placed alongside the plants being clipped or place a bag over the seed heads before clipping to minimize seed loss. Plastic between rows is recommended so dehisced seeds can be salvaged.
Vacuum: Not recommended.
Seed stripper: Not recommended.
Combine/thresher settings: Run at 885 rpm with 4 mm gap.
Seed cleaning: Put through vacuum separator with speed set high and suction set to low to remove dust and <5% of seeds. Fanning mill separation can be used instead, and should also work well if needed.
Storage requirements: Cool dry conditions.

Considerations for Use in Revegetation

Lathyrus ocrholeucus occurs naturally on disturbed sites in Alberta (Smreciu 1993), though it is reported to be a poor colonizer of disturbed sites, and a poor competitor (*Ritchie and Tilman 1995).

In Alberta, this species is reported to grow on medium textured wet to mesic soils (Gerling et al. 1996).

Lathyrus ochroleucus can tolerate mild soil salinity and low nitrogen soils, but appears to be restricted to soils with near-neutral pH ranges (Hardy 1989).

Lathyrus ochroleucus fixes nitrogen, so may be beneficial as a soil builder in a seed mixture used for reclamation (Hardy 1989).

It is reported to have moderate to excellent forage value for livestock (particularly sheep) and mule deer (Gerling et al. 1996, Smreciu 1993, Pahl and Smreciu 1999). The leaves are rich in protein and are commonly sought by horses, cattle and sheep during early growth (*Johnson et al. 1995).

**fide* Silzer 2000.

Lathyrus ochroleucus Hook. creamy peavine (continued)

Other considerations

Lathyrus ochroleucus is the same genus as the cultivated annual garden sweet pea, and this perennial species may also have potential as a native ornamental vine; it may be especially suitable as a vine for covering chain link fences.

Notes

Lupinus arcticus S. Wats.
Arctic lupine **Family: Fabaceae**

Figure 66. Documented range of *Lupinus arcticus* in northern British Columbia.

Figure 67. Growth habit of *Lupinus arcticus* under cultivation.

Lupinus arcticus S. Wats. Arctic lupine (continued)

Background Information

Lupinus arcticus is found north to Alaska, the Yukon and Northwest Territories, and south to northern Oregon and southeastern Alberta. It is reported to be very common throughout British Columbia, except it is absent from the Queen Charlotte Islands (Taylor 1974, Douglas et al. 1999a). Two subspecies are recognized: *L.a.* ssp. *subalpinus* (Piper & B.L. Robins.) Dunn is characterized by more cauline (stem) leaves and is more abundant south of 55°N. *L.a.* ssp. *arcticus* has mostly basal leaves and is the common form north of 55°N (Douglas et al. 1999a). We did not distinguish the two subspecies in our collections, and noticed many intermediate forms; our seed production plots include both forms and their intermediates.

Growth Form: Branched woody stem base; palmate compound leaves originate at the base of the plant in the north subspecies, but along the stem in the southern subspecies; 6–10 pointed to rounded leaflets; bluish elongated cluster of pea-like flowers; mature plant size to 60 cm tall (MacKinnon et al. 1992, Douglas et al. 1999a). Forms nitrogen-fixing symbiotic root nodules with *Rhizobium* bacteria.

Site Preferences: Found in early successional ecosystems, in moist to mesic open clearings, slash-burned clearcuts formerly occupied by *Picea englemanii* and *Pinus contorta* var. *latifolia*, gravel bars, meadows, roadsides, open forests, and some dry slopes (Quinton 1984, Klinka et al. 1989, MacKinnon et al. 1992, Douglas et al. 1999a). Widely distributed in the ESSF but restricted to drier sites in the wetter sub-zones; found only in the moist subzone in the SBS on modal sites; found on impoverished sites in the BWBS (SNR >C, SMR 3-5); on poor dry sites in SBPSmc and on poor to rich sites in the SBPS (SMR 2-4). Reported to be shade intolerant and to increase in abundance in pioneer and young seral stages (Beaudry et al. 1999). We have observed very high abundance (ca. 5-15% cover) in an SBSmc clearcut two or three years after logging; it almost completely disappeared the following year. Similarly, Hendrickson and Burgess (1989) reported 21,600 *Lupinus arcticus* stems per ha with a biomass of 159 kg/ha on a lodgepole pine site logged four years earlier.

Seed Information

Seed Size: Length: 3.65 mm (3.25 - 4.09 mm)
Width : 2.65 mm (2.19 - 3.06 mm)

Seeds per gram: 108 (range: 98 - 121)

Volume to Weight Conversion: 709.0 g/L at 97.2% purity

Germination Capacity: At 30°/20° C untreated: 40.1%
(23% -60%)
stratified: 46%
scarified/stratified: 95.2%
At 25°/15° C untreated: 72.7%
(70 -75%)
stratified: 44.3%

Figure 68. Seeds of *Lupinus arcticus*. Rule divisions are 1.0 mm.

The seed from pods harvested while still green had 13% lower germination than seed from fully ripened pods (Burton and Burton 2001b).

Germination Speed: To first germination: 6.5 days
To 50% potential: 14.2 days

Seed Longevity: Seeds stored in our warehouse for one year, under cool dry conditions, had higher germination rates in the second year after harvest. There are reports that *Lupinus arcticus* seeds may retain their viability for hundreds or even thousand of years (Porsild et al. 1967).

Lupinus arcticus S. Wats. Arctic lupine (continued)

Considerations for Growing

Techniques for Seed Production

Seed treatment: High germination may be attained with a combined pre-germination treatment of stratification and scarification. Emery (1964) suggests that fresh seeds of perennial lupines do not require pretreatment but stored seeds require hot water or acid scarification. Under laboratory conditions, scarifying seeds increases and hastens germination at both $30^{o}/20^{o}$ C and $25^{o}/15^{o}$ C.

Soil considerations: *Lupinus arcticus* can grow in loam, sandy loam or gravelly soil. Untreated seeds germinate best in cooler soils.

Stand establishment: Site should be free of all weeds, especially rhizomatous grasses and other persistent species because there are currently no selective herbicides that can be used once plants are growing.

Row spacing: Unknown; suggest 75 to 120 cm under dryland conditions, 30 to 90 cm with good irrigation.

Seeding density: Unknown at present; suggest 60-100 PLS seeds per linear metre (Smith and Smith 2000).

Seeding depth: 1 cm (Pahl and Smreciu 1999).

Stand maintenance: Regularly cultivate rows and spot spray with herbicide to keep plot weed free; annual fertilization with low N formulations may extend the life of the plot. Stands may be relatively short lived (3 to 5 years), especially if subject to competition from grasses or annuals. *Lupinus arcticus* is a host for a *Macrosiphum alibifrons* (lupine aphid; Cohen 1986), but its effects on seed yield appear to be negligible.

Harvesting and Seed Processing

Dates of selective harvesting in the Bulkley Valley of northwestern B.C. range from July 10th to August 26th. Timing of harvest is important as pods dehisce very easily when ripe.

Hand clipping: Use sharp hand clippers. Hold the seed heads over bins placed alongside the plants being clipped or place a bag over the seed heads before clipping to minimize seed loss. Do not allow seeds to become over-ripe or pods will dehisce before harvest and you will lose many seeds. Plastic between rows is recommended so dehisced seeds can be salvaged. It has been our experience that as soon as some of the pods (typically the top ones) on the seed stalk have turned dark (black or brown), one can safely clip the entire the stalk and allow the remaining seeds to ripen in the pod while curing in the sun.

Vacuum: Not recommended.

Seed stripper: In our experience these seeds easily dehisce when ripe, so use of a seed stripper is not recommended. However, Young and Young (1990) suggest that *Lupinus* sp. can be harvested with a seed stripper.

Combine/thresher settings: Run at 1241 rpm with 4 mm gap. Remove seed shaken loose after each batch before rethreshing more uncleaned seed; any remaining cleaned seeds will crack otherwise. After threshing is completed, remove any intact pods from the thresher and run through once more to remove any remaining seed.

Seed cleaning: Put through fanning mill with the following configurations: prescreen 4.9 mm round; top screen 4.8 mm round, bottom screen 1.2 mm square. If pods and trash are still abundant, put through a second time with a just 4 mm square top screen (or hand screen), then through a vacuum separator with speed set high and suction set to low to remove dust and <5% of seeds.

Lupinus arcticus S. Wats. Arctic lupine (continued)

(Harvesting and Seed Processing, continued)

Storage requirements: Cool dry conditions, though seeds are long-lived in nature under a wide range of conditions.

Considerations for Use in Revegetation

Despite a hard seed coat and beneficial response to scarification, we have observed good levels of emergence under both spring and fall sowing in the field.

Lupinus arcticus is a nitrogen fixer (reported to fixing at least 2 kg/ha per year in a four year old clear-cut; Hendrickson and Burgess 1989), so is a valuable soil-building species on degraded sites.

This species can be used as the principal legume in a native grass-legume mix for erosion-control and roadside seeding in much of northern British Columbia, especially on gravelly soils.

Lupines are potentially poisonous to animals so are not recommended for use where domestic livestock can be found (Davis 1982, MacKinnon et al. 1992, Majak et al. 1994). Sheep are the most common victims, but cattle are also affected (Davis 1982).

According to Davis (1982) and Davis and Stout (1986), certain lupines may contain the alkaloid anagyrine which is responsible for "crooked cow disease" if engested by pregnant cows at certain stages in their pregnancy.

The similar species *Lupinus sericeus* is not considered toxic to wildlife.

Other considerations:

Lupinus arcticus, with its attractive blue flowers, has potential as an ornamental species.

Notes

Lupinus polyphyllus Lindl. ssp. *polyphyllus*
large-leaved lupine **Family: Fabaceae**

Figure 69. Documented range of *Lupinus polyphyllus* in northern British Columbia.

Figure 70. Growth habit of *Lupinus polyphyllus* in cultivation.

Lupinus polyphyllus Lindl. ssp. *polyphyllus* large-leaved lupine (continued)

Background Information

Dunn (1965) reports the natural range of *Lupinus polyphyllus* extending from California into British Columbia on wet sites in areas of high rainfall with cool nights, cold winters and a fog belt. Sub-species seem to be more recognizable on drier sites. Douglas et al. (1999a) reported it found in southwestern and south-central British Columbia, less frequently northward, but as far as southeastern Alaska, and south to Idaho and California. Only one subspecies is recognized in B.C., *L.p.* ssp. *polyphyllus* (Douglas et al. 1999a).

Growth Form: Stems cylindrical, hollow at base, 9 - 17 leaflets per leaf, pointed at tip; bluish to violet dense cluster of pea-like flowers; mature plant size up to 150 cm tall. Forms nitrogen-fixing symbiotic root nodules with *Rhizobium* bacteria.

Site Preferences: Moist to mesic meadows, gravel bars, stream banks, clearings, roadsides and open forests (MacKinnon et al. 1992, Douglas et al. 1999a). Often found on heavier (i.e., more clayey) soils than *L. arcticus*.

Seed Information

Seed Size: Length: 3.83 mm (3.48 - 4.31 mm)
Width: 2.67 mm (2.31 - 2.96 mm)

Seeds per gram: 96 (range: 71 - 140)

Volume to Weight Conversion: 704.7 g/L at 97.7% purity

Germination Capacity: At 30°/20° C untreated: 58.3%
(42% - 81%)
scarified/stratified: 72.8%
At 25°/15° C untreated: 77.0%
(73 – 81%)
stratified: 67.0%
(43 – 91%)

The seed from pods harvested while still green had 12% lower germination then seed from fully ripened pods.

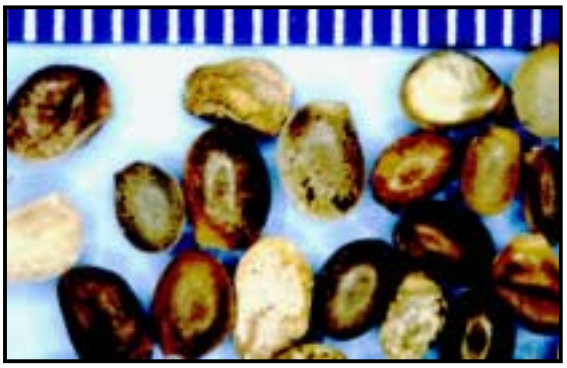

Figure 71. Seeds of *Lupinus polyphyllus*. Rule divisions are 1.0 mm.

Germination Speed: To first germination: 7.9 days.
To 50% potential: 21.5 days.

Seed Longevity: In our research to date, seeds have retained their viability for two years after storage under cool dry conditions.

Considerations for Growing

Techniques for Seed Production

Seed treatment: Scarification seems to be beneficial, but stratification for two months at 5°C was not, at least not when tested at cooler germination temperatures. Under lab conditions, scarifying the seed increases and hastens germination at both 30°/20° C and 25°/15 ° C. In untreated seeds, germination is higher when seeds are tested at 25°/15° C. This suggests this species prefers cool temperatures to germinate, so fall planting is recommended.

Soil considerations: *Lupinus polyphyllus* can grow in clay loam, loam, sandy loam or gravelly soil. Untreated seeds germinate best in cooler soils.

Lupinus polyphyllus Lindl. ssp. *polyphyllus* large-leaved lupine (continued)

(Techniques for Seed Production, continued)

Stand establishment: Site should be free of all weeds, especially rhizomatous grasses and other persistent species because there are currently no selective herbicides that can be used once plants are growing.
Row spacing: Unknown; suggest 75 to 120 cm under dryland conditions, 30 to 90 cm with good irrigation.
Seeding density: Unknown at present; suggest 60-100 PLS seeds per linear metre (Smith and Smith 2000),
Seeding depth: 1 cm (Pahl and Smreciu 1999).
Stand maintenance: Regularly cultivate rows and spot spray with herbicide to keep plot weed free; annual fertilization with low N formulations may extend the life of the plot. Voronov (1974) reports plants survived for up to four years, but seed yields decreased sharply in the third year. This finding is corroborated in our own research. Voronov (1976) also reports that inbreeding was accompanied by a marked decrease in flower number, pod set and seed yield. *Lupinus polyphyllus* is a host for a *Macrosiphum alibifrons* (lupine aphid; Cohen 1986), and seems to suffer some loss of flowers (and presumably seed yields too) as a result.

Harvesting and Seed Processing:
Dates of selective harvesting in the Bulkley Valley of northwestern B.C. range from July 17th to as late as October 16th. Timing of harvest is important as seeds dehisce very easily when ripe.
Hand clipping: Use sharp hand clippers. Hold the seed heads over bins placed alongside the plants being clipped or place a bag over the seed heads before clipping to minimize seed loss. Do not allow seeds to become over-ripe or pods will dehisce before harvest and you will lose many seeds. Plastic between rows is recommended so dehisced seeds can be salvaged. The preferred time for harvest is as soon as some of the pods (typically the top ones) on the flower stalk have turned dark (black or brown); one can then safely clip the entire stalk and allow the remaining seeds to ripen in the pod while curing in the sun.
Vacuum: Not recommended.
Seed stripper: In our experience these seeds easily dehisce when ripe, so use of a seed stripper is not recommended. However, Young and Young (1990) suggest that *Lupinus* sp. can be harvested with a seed stripper.
Combine/thresher settings: Two runs at 885 rpm with 4 mm gap; note that *L. polyphyllus* could not withstand the same thresher setting as *L. arcticus* (1241 rpm), suggesting it may have a softer seed coat. Remove the seed shaken loose after each batch before threshing more uncleaned seed, as cleaned seeds will crack otherwise; after threshing is completed, remove any unopened pods from the thresher and run them through once more to remove any remaining seed.
Seed cleaning: Put through fanning mill, using the following configuration: prescreen 4.9 mm round; top screen 4.8 mm round; bottom screen 1.2 mm square. If there are still unshelled pods and trash, put through a top screen only of 4 mm square (or use a 4 mm square hand screen), followed by use of a vacuum separator with speed set high and suction set low to remove dust and <5% of seeds.
Storage requirements: Cool dry conditions; seeds stored in pods have lower germination (Styk 1970).

Lupinus polyphyllus Lindl. ssp. *polyphyllus* large-leaved lupine (continued)

Considerations for Use in Revegetation

Lupinus polyphyllus fixes nitrogen so is a valuable species on degraded sites, especially those with heavier (finer) soils; excellent tap root growth may also have value for decompacting soils.

At low levels of phosphorus, *Lupinus polyphyllus* appears more effective than some domestic legumes at fixing nitrogen (Davis 1991).

Lupinus polyphyllus seems to be suited to warmer locales and microsites, and finer soils, than *L. arcticus*.

Potentially poisonous to animals so not recommended for use where domestic livestock can be found (Davis 1982, MacKinnon et al. 1992, Majak et al. 1994). Sheep are the most common victims, but cattle are also affected (Davis 1982).

According to Davis (1982) and Davis and Stout (1986) certain lupines may contain the alkaloid anagyrine, which is responsible for "crooked cow disease" if ingested by pregnant cows at certain stages in their pregnancy.

Other considerations

Some lines of *Lupinus polyphyllus* have been domesticated and selected for ornamental use throughout North America.

Lupinus polyphyllus has been used for soil enrichment (plowed under as a “green manure”) in Europe (Dovban 1994).

Lupinus polyphyllus can intergrade with *L. nootkatensis, L. arcticus, L. burkei* and *L. perennis* (Dunn and Gillett 1966).

Notes

Vicia americana Muhl. *ex* Willd.
American vetch **Family: Fabaceae**

Figure 72. Documented range of *Vicia americana* in northern British Columbia.

Figure 73. Growth habit of *Vicia americana* grown in cultivation, in the open.

Vicia americana Muhl. *ex* Willd. American vetch (continued)

Background Information

Vicia americana is found north to southeast Alaska and the Northwest Territories, east to Quebec and New Brunswick, and south to West Virginia, Ohio, Kansas, New Mexico and California. It is common in the southern two-thirds of B.C., but is less frequent northward and is absent from the Queen Charlotte Islands (Taylor 1974, Douglas et al. 1999a).

Growth Form: Rhizomatous herb with a single trailing or climbing stem, which is ridged; 8-18 leaflets with bluish purple to reddish purple pea-like flowers in a loose terminal cluster (Figure 73); stipules are pointed and toothed; mature plant size is 15 - 100 cm tall (MacKinnon et al. 1992, Douglas et al. 1999a). Forms symbiotic root nodules with nitrogen-fixing *Rhizobium* bacteria.

Site Preferences: Moist to mesic meadows, thickets and open forests at low to middle elevations; dominant in aspen or mixedwood stands in the southern half of the northern Interior (MacKinnon et al. 1992, Douglas et al. 1999a). In B.C. it is reported to be shade tolerant to shade intolerant, to persist in pioneer seral stands, and to increase in abundance in deciduous and mixed young and mature seral stages especially in the BWBS (Klinka et al. 1989, Beaudry et al. 1999). Distributed in the SBS on richer sites (SNR >D, SMR 2-5), and on rich moist sites in the BWBS; found over a narrow range on moderately fertile sites (SNR C-D) in the SBPS (Beaudry et al. 1999). May prefer heavy (clayey) soils (Rose et al. 1998).

Seed Information

Seed Size: Length: 3.17 mm (2.76 - 3.76 mm)
Seeds per gram: 67 (range: 62 - 74)
Volume to Weight Conversion: 743.1 g/L at 88.3% purity
Germination Capacity: At 30°/20° C untreated: 85.0%
At 25°/15° C untreated: 87.3%
stratified: 85.7%
Germination Speed: To first germination: 14.3 days
To 50% potential: 29.9 days
With scarification: 3-7 days;
Without scarification: 14 days (Pahl and Smreciu 1999).
Seed Longevity: Unknown; probably many years, as found for other hard-coated legumes.

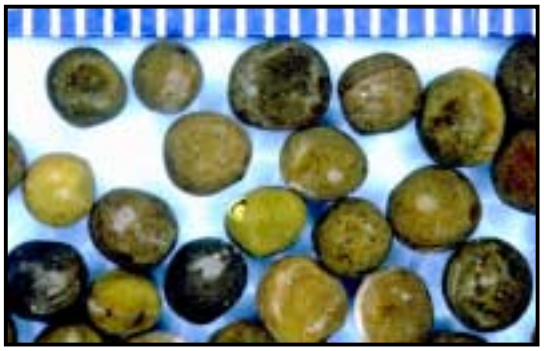

Figure 74. Seeds of *Vicia americana*. Rule divisions are 1.0 mm.

Considerations for Growing

Techniques for Seed Production

Seed treatment: Scarification or stratification may accelerate germination, but does not improve overall germination capacity; so we recommend no pre-germination treatments before sowing; seeds should be at least one year old when sown (Rose et al. 1998).

Soil considerations: Plant in a moist clayey soil in an area with at least 8 hours of direct light per day (Rose et al. 1998).

Stand establishment: Plant in the spring or fall in a site free of weeds, especially rhizomatous grasses and other persistent species, because there are currently no selective herbicides that can be used once plants are growing.

Vicia americana Muhl. *ex* Willd. American vetch (continued)

(Techniques for Seed Production, continued)

Row spacing: Row cropping recommended with 60 cm spacing.
Seeding density: 100-150 PLS seeds per linear metre.
Seeding depth: 1 cm (Pahl and Smreciu 1999).
Stand maintenance: Regularly cultivate rows and spot spray with herbicide to keep plot weed free. Stand life is generally only two to three years (confirming cmments by Pahl and Smreciu 1999); annual fertilization with low N formulations may extend the life of the plot.

Harvesting and Seed Processing
Dates of selective harvesting in the Bulkley Valley of northwestern B.C. have ranged from August 4th to September 8th. Timing of harvest is important as pods dehisce very easily when ripe.
Hand clipping: Use sharp hand clippers or pick pods or pod clusters by hand. Harvest the seedpods as they turn brown. Hold the seed heads over bins placed alongside the plants being clipped or place a bag over the seed heads before clipping to minimize seed loss. Do not allow seeds to become over-ripe or pods will split before harvest and you will lose many seeds. Plastic between rows is recommended so dropped seeds can be salvaged.
Vacuum: Not recommended.
Seed stripper: Not recommended, as pods are not held above dense foliage.
Mechanical harvesting: It has been suggested that mechanical harvesting is feasible and simpler if this species is grown with a sparse nurse crop such as alfalfa, the seeds of which can then be easily separated from *Vicia americana* seeds. Care should be taken with any method of harvest because *V. americana* is a very slender plant and is easily uprooted (Pahl and Smreciu 1999).
Combine/thresher settings: 885 rpm with 4 mm gap. Remove seed shaken loose after each batch before threshing uncleaned seed (cleaned seeds will crack otherwise); after threshing is completed, remove any intact pods from thresher and run through once more to remove any remaining seed.
Seed cleaning: Put through fanning mill with the following configuration: prescreen 4 x 19 mm slot; top screen 4.89 mm round; bottom screen blank. Then put through vacuum separator with speed set high and suction set to low to remove dust and <5% of seeds.
Storage requirements: Cool dry conditions.

Considerations for Use in Revegetation

In Alberta, this species is reported to grow on medium to coarse textured mesic soils (Gerling et al. 1996), and has been found growing naturally on coal mine spoils (Strong et al. 1978).

Vicia americana is a nitrogen fixer which has been successfully used for revegetation in alpine tundra in B.C.

Baker and Reid (1977) report that *Vicia americana* accumulates more phosphorus and zinc than other legume species.

It has excellent forage value and is palatable to livestock and wildlife (Hardy 1989, Gerling et al. 1996).

This species can be the main legume of revegetation mixes where consumption by livestock or wild ungulates is anticipated or intended.

Vicia americana is a common species in fescue grasslands in Alberta, mixed-grass prairies and mixedwood areas (Pahl and Smreciu 1999).

Vicia americana Muhl. *ex* Willd. American vetch (continued)

(Considerations for Use in Revegetation, continued)

*Wasser (1982) and Sieg et al. (*1983) report that *Vicia americana* may be useful in revegetating open or depleted trembling aspen rangelands, including burned over or thinned conifer areas and coal mined lands, roadsides and critical site stabilization areas, as well as for beautification.

* *fide* Coladonato 1993.

Other considerations

Vicia americana has potential as a climbing ornamental species, or as ground cover.

Notes

Composites

***Achillea millefolium* L.**
common yarrow **Family: Asteraceae**

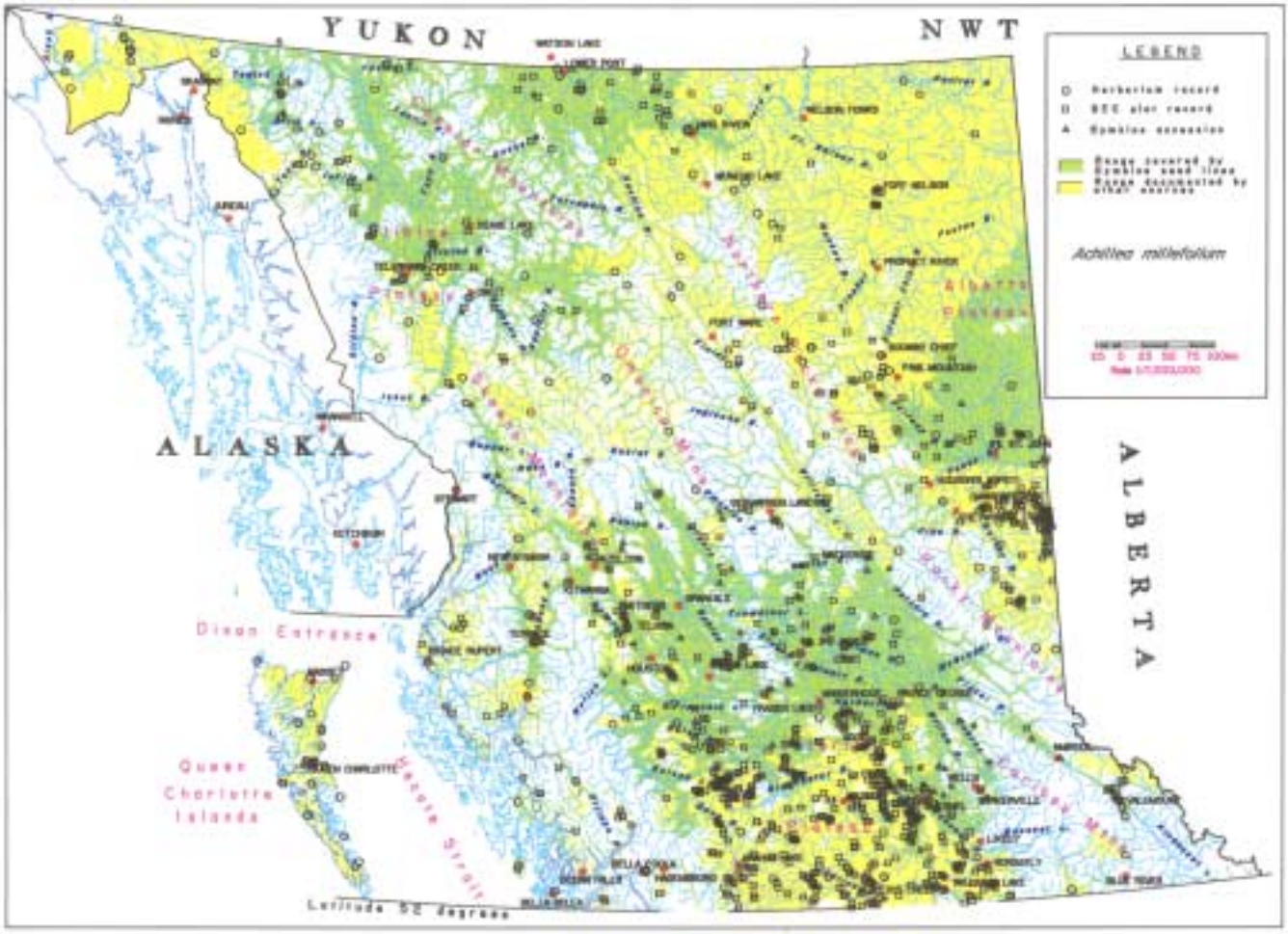

Figure 75. Documented range of *Achillea millefolium* in northern British Columbia.

Figure 76. Growth habit of *Achillea millefolium* in cultivation.

Figure 77. Mature *Achillea millefolium* plant.

Figure 78. *Close-up of Achillea millefolium* flowers.

Achillea millefolium L. common yarrow (continued)

Background Information

Though circumpolar and a common component of European meadows and hayfields, research suggests that most of the yarrow found in Canada is native to North America (Frankton and Mulligan 1970). Most populations in the northern interior of British Columbia are probably *A.m.* var. *lanulosa (Nutt.)* Piper in Piper & Beattie, but may also include the shorter *A.m.* var. *alpicola* (Rydb.) Garrett (Douglas et al. 1998) at higher elevations; we did not distinguish among varieties in acquiring our accessions. Several varieties of this species, primarily of European origin, have been developed for distinctive flower colours and are marketed as ornamentals; others are grown in cultivation for medicinal purposes. A series of classic studies in population genetics conducted in the 1940's and 1950's identified strong ecotypic variation along elevational gradients (Hiesey and Nobs 1970). Flowers rarely self-pollinate, probably because anthers (male) appear before receptive stigmas (female) in individual flowers, and are largely insect pollinated (Pojar 1974). See Warwick and Black (1982) for a thorough overview of the biology of *Achillea millefolium.*

Growth Form**:** Aromatic rhizomatous perennial herb. Vegetative growth starts with a dense rosette of fern-like leaves typically less than 10–15 cm tall. Flowering stalk to 60 cm tall has spaced, alternate fern-like leaves and terminal clusters of 5 white to pink ray flowers and 10-40 cream coloured disk flowers (Douglas et al. 1998, MacKinnon et al. 1992).

Site Preferences: Variously reported to grow most abundantly on dry to moist, or mesic to dry well-drained open sites, at low to high elevations; does well on disturbed sites and poor soils but is intolerant of shade (MacKinnon et al. 1992, Small and Catling 1998, Douglas et al. 1998). Widely distributed in the SBPS (SMR <7), found on dry rich sites in the SBS (SMR<5, SNR>A), though restricted to sites of SMR<3 and SNR B-C in moist SBS subzones. Found on circum-mesic sites in the ESSF (SMR 2-5, SNR B-D), though more restricted in the wetter subzones; restricted in the BWBS to moister sites (SMR>5) and subzones (Beaudry et al. 1999).

Seed Information

Seed Size: Length: 2.15 mm (1.82 - 2.48 mm)
Width: 0.78 mm (0.61 - 0.94 mm)
Thickness: 0.30 mm (0.22 - 0.35 mm)

Seeds per gram: 8,105 (range: 6,073 - 9,417)

Volume to Weight Conversion: 132.5 g/L at 40.6% purity
205.3 g/L at 72.5% purity

Germination Capacity: At 30°/20° C untreated: 81.4% (65 - 98%)
At 25°/15° C untreated: 91.5% (86 - 96%)
stratified: 90.5% (86 - 95%)

Germination Speed: To first germination: 5.0 days
To 50% potential: 6.0 days

Seed Longevity: at least 5 years under cool dry conditions.

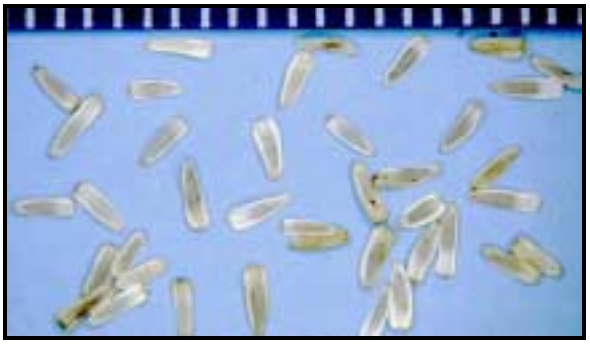

Figure 78. Seeds of *Achillea millefolium*. Rule divisions are 1.0 mm.

Achillea millefolium L. common yarrow (continued)

Considerations for Growing

Techniques for Seed Production

Soil considerations: Establish on loamy, well prepared soils, with a firm seedbed. Germination tests suggest that *Achillea* will germinate best on cooler soils (early or late in the growing season).
Stand establishment: Site should be free of all weeds, especially rhizomatous grasses and other persistent species because there are currently no selective herbicides that can be used once plants are growing. Stands can be established from excised rhizomes (Bourdôt 1984, Rose et al. 1998), from seedlings started in the greenhouse, or from seed sown in spring or fall. Germination from seed is excellent; the bottom photo on the front cover of this manual shows an *Achillea millefolium* seed production plot established from seed using a single-row push seeder.
Row spacing: 60-90 cm.
Seeding density: 375 PLS seed per linear metre of row.
Seeding depth: Surface (Pahl et al. 1999), or no more than 6 mm deep (Pyke and Borman 1993). A light dusting of peat moss or dry soil will help keep the seeds in place.
Stand maintenance: Regularly cultivate rows and spot spray with herbicide to keep plot weed free; our plots were productive for only two years after establishment without fertilizer inputs, though plants did regenerate vegetatively and filled in the plot. Assuming good soil quality, Pahl and Smreciu (1999) estimate the stand life to be approximately 4 years. Annual applications of a low-nitrogen fertilizer may help extend stand life. Plastic placed between rows will not only serve as mulch but will catch easily shattered seeds which can later be vacuumed or swept up.

Harvesting and Seed Processing

Dates of selective harvesting in the Bulkley Valley of northwestern B.C. have ranged from July 25th to November 1st (starting from July 25th to August 19th). Some seeds are retained in seed heads until late fall if protected from wind.
Hand clipping: Hold the seed heads over bins placed alongside the plants being clipped, or place a bag over the seed heads and bend them over before clipping to minimize seed loss.
Vacuum: Vacuum ripe seed heads selectively as they ripen by placing the vacuum intake completely over seed head.
Seed stripper: Seed sheds and scatters moderately easily, so seed stripping should be done with a fine brush stripper and a vacuum attachment, if possible.
Combine/thresher settings: 885 rpm with 6 mm gap.
Seed cleaning: Fanning mill (no air flow), followed by vacuum separator. Fanning mill screen sizes: prescreen 1.8 x 12.5 mm slot; top screen 1.2 x 7.1 mm slot; bottom screen blank or 1.40 mm square. Then use vacuum separator with speed and suction set low to remove dust and <5% of seeds. Hand sieve using a #14 (1.40 mm) screen for small quantities or for finishing.
Seed storage: Cool dry conditions (0.6^{o}–7.2^{o} C; Link 1993).

Considerations for Use in Revegetation

Achillea millefolium makes a valuable contribution to many seed mixtures, being added where a fast-germinating, low-growing, rhizomatous non-graminoid species is desired.

Achillea can effectively control erosion, due to good ground cover by basal leaves and its extensive system of rhizomes (Shaw and Monsen 1983).

Achillea millefolium L. common yarrow (continued)

(Considerations for Use in Revegetation, continued)

Drill seed 6 mm deep or broadcast seed, then cover with a similar depth of soil at a rate of 431 to 646 PLS per m^2 under ideal moist conditions; double the rate when broadcast seeding and for harsh, erosive and south- or west-facing or dry sites (Pyke and Borman 1993).

Yarrow is moderately resistant to grazing, due to its aromatic nature and/or bitter taste, so can act as a deterrent to wildlife and cattle; it has poor to fair forage value (Aleksoff 1999, Gerling et al. 1996, Small and Catling 1998). As a result, this species is generally an "increaser" under heavy grazing pressure, and its rhizomatous growth form also allows it to recover and increase after light fire (Aleksoff 1999). We note, however, that deer will eat flower heads.

Rapid germination and good establishment on degraded soil means this species can provide quick ground cover and is very useful for erosion control (Small and Catling 1998).

Common yarrow withstands mowing, so has great potential for lawn cover or roadside revegetation (Connelly 1991, Small and Catling 1998).

Achillea is reported to grow on medium to coarse textured wet to dry soils in Alberta and to be tolerant of drought and acidic soils (Gerling et al. 1996). It has also been observed as an invader of coal minespoils in Alberta and the U.S.A. (Russell 1985, Uresk and Yamamoto 1986).

Vigorous early growth in new habitats slows down as a plant community establishes around *Achillea,* so this plant is rarely aggressive despite its rhizomatous habit. This species is moderately competition-tolerant (Goldberg 1987, *Higgins and Mack 1987, Gurevitch et al. 1990) so long as it remains unshaded by trees and shrubs, and can persist in mature grassland communities.

* *fide* Aleksoff 1999.

Other Considerations:

Achillea millefolium has been widely used medicinally in North America and Europe for millennia (Shemluck 1982, Small and Catling 2000).

Extracts from yarrow foliage are currently present in more than 20 pharmaceutical products marketed in Canada (Small and Catling 1998, 2000).

Proven mosquito repellent (Tunon et al. 1994).

Has still untapped potential as an ornamental, food and medicinal crop (Chandler et al. 1982, Small and Catling 1998, 2000, Marles et al. 2000).

Has potential for use as a residential lawn cover, as it can withstand trampling, mowing and infrequent watering (Connelly 1991).

Notes:_____

Anaphalis margaritacea (L) Benth. and Hook. F. *ex* C.B. Clarke

pearly everlasting **Family: Asteraceae**

Figure 79. Documented range of *Anaphalis margaritacea* in northern British Columbia.

Figure 80. Growth habit of *Anaphalis margaritacea* in cultivation.

Anaphalis margaritacea pearly everlasting (continued)

Background Information

Anaphalis margaritacea can be found north to Alaska, the Yukon and Northwest Territories, east to Newfoundland and Nova Scotia, and south to North Carolina, Kentucky, Arizona, New Mexico and California. It is reported to be common throughout B.C. except in the northeast (Douglas et al. 1998).

Growth Form: Rhizomatous perennial herb, with few basal leaves, alternate stem leaves light green above, woolly white underneath; flower heads in dense flat-topped clusters, yellowish disk flowers; involucral bracts dry pearly white; mature plant size is 20-90 cm tall (MacKinnon et al. 1992, Douglas 1998).

Site Preferences: Moist to dry meadows, rocky slopes, open forest, landings, roadsides and other disturbed sites from low to subalpine elevations, throughout most of B.C. In coastal B.C., it is reported to be shade-intolerant and occupies exposed mineral soil on disturbed sites and water-shedding sites up to the alpine (Klinka et al. 1989).

Seed Information

Seed Size: Length: 0.97 mm (0.85 - 1.07 mm).
Width : 0.32 mm (0.24 - 0.37 mm).

Seeds per gram: 24,254 (range: 13,375 - 37,167).

Volume to Weight Conversion: 374.0 g/L at 66.7.5% purity.

Germination Capacity: At 30°/20° C untreated: 62.8% (42 - 84%).
At 25°/15° C untreated: 86.1% (75 - 97%).
stratified: 54.5% (23 – 86%).

Germination Speed: To first germination: 13.3 days.
To 50% potential: 26.2 days.

Seed Longevity: At least three years. In our research, *Anaphalis margaritacea* seeds two and three years old remained viable, with germination levels 15 - 18% greater than seeds grown and tested in the year they were harvested, suggesting that some after-ripening or inadvertent stratification may occur in seeds over time.

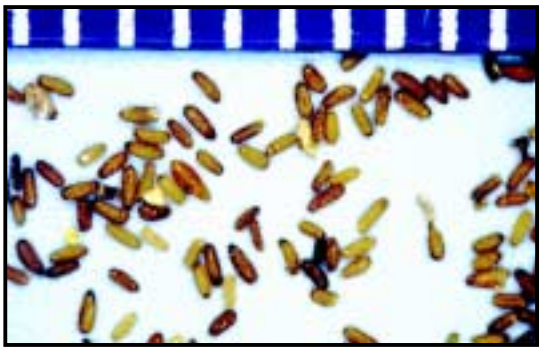

Figure 81. Seeds of *Anaphalis margaritacea*. Rule divisions are 1.0 mm.

Considerations for Growing

Techniques for Seed Production

Seed treatment: Tests indicate that untreated seeds germinate best under cool conditions, and that there is no benefit to stratification.

Soil considerations: Establish on loamy, finely tilled and well prepared soils with a firm seedbed.

Stand establishment: Site should be free of all weeds, especially rhizomatous grasses and other persistent species because there are currently no selective herbicides that can be used once plants are growing. Stands can either be established from seedlings started in the greenhouse or from seed, sown in spring.

Row spacing: 60–90 cm.

Seeding density: 300-400 PLS seed per linear metre.

Anaphalis margaritacea **pearly everlasting (continued)**

(Techniques for Seed Production, continued)

Seeding depth: Surface to shallow; a light dusting of peat moss or loose soil will help to keep the seeds in place.
Stand maintenance: Regularly cultivate rows and spot spray with herbicide to keep plot weed free; annual fertilization with low N formulations may extend the life of the plot. Plastic placed between rows will not only serve as mulch but will catch easily scattered seeds which can later be vacuumed or swept up.

Harvesting and Seed Processing
Dates of selective harvesting in the Bulkley Valley of northwestern B.C. have ranged from August 13th to October 21st. Link (1993) suggests that *Anaphalis* should be harvested when the centre of the flower is dark brown in late August to mid-September. Timing of harvest is important, as seed is easily scattered by the wind after it is ripe.
Hand clipping: Hold the seed heads over bins placed alongside the plants being clipped or place a bag over the seed heads before clipping to minimize seed loss.
Vacuum: A shop vacuum works best for this species. Hold hose over ripe, completely dry flower heads and turn on suction. Empty the canister as it fills. Modified leaf blower is not suitable for this species because fabric collection bag allows the small seeds to seep out.
Seed stripper: Not recommended.
Combine/thresher settings: Repeated runs at 1850 rpm with 1 mm gap.
Seed cleaning: Fanning mill (no air flow) twice, follow with hand sieving. Fanning mill screen sizes first run: prescreen 1.2 x 7.1 mm slot; top 1.8 x 12.7 mm slot; bottom blank; second run: prescreen 0.5 mm square; top 1.8 x 12.7 mm slot; bottom blank; then use vacuum separator with speed and suction set low to remove dust and <5% of seeds; can use hand sieve (0.5 mm screen) for finishing or as the main cleaning for small quantities.
Storage requirements: Cool, dry conditions (Link 1993).

Considerations for use in revegetation

Anaphalis margaritacea is reported to grow well on medium to coarse textured mesic to dry soils on open woods in foothills, mountains and dry pastures in Alberta (Gerling et al. 1996).

This species establishes slowly so it should not be counted on for quick cover or erosion control; suitable for subsoil materials and compacted soils resulting from recent roadbuilding activities.

Anaphalis can successfully colonize on low nitrogen soils (Chapin 1994).

It can be sown by direct broadcast seeding and raking in as part of a grass/forb mixture (Link 1993).

Other considerations

Anaphalis was traditionally used as a poultice for sores and swellings by West Coast Natives and as a medicine for internal disorders (Turner and Bell 1973, Turner et al. 1980).

This species has potential for use in floral arrangements and craft products, as its flower heads dry well (Douglas 1995).

Anaphalis margaritacea **pearly everlasting**
(continued)

Notes

Arnica chamissonis Less. ssp. *foliosa* (Nutt.) Maguire

meadow arnica **Family: Asteraceae**

Figure 82. Documented range of *Arnica chamissonis* in northern British Columbia.

Figure 83. Growth habit of *Arnica chamissonis* in cultivation.

Arnica chamissonis ssp. *foliosa* meadow arnica (continued)

Background Information

Arnica chamissonis is found north to Alaska and the Yukon Territories, east to Ontario and south to New Mexico, Arizona and California. It is commonly found in B.C. (Douglas et al. 1998). MacKinnon et al. (1992) report that it is found scattered throughout northern British Columbia, but that it is locally abundant where it is found. Three subspecies are recognized in B.C.; the accessions with which we have been working are all *A.c.* ssp. *foliosa* (Nutt.) Maguire (Douglas et al. 1998). As occurrences and collections are often not identified to subspecies, subspecies are not distinguished in the range map presented in Figure 82.

Growth Form: Rhizomatous perennial herb; 5-10 pairs of opposite stem leaves; yellow ray and disc flowers; mature plant size is 20-100 cm tall, one of the tallest *Arnicas.* Spreads easily from rhizomes, but can be propagated from seed as well (Douglas 1982, MacKinnon et al. 1992, Douglas et al. 1998).

Site Preferences: Wet to mesic meadows and forest openings, found throughout northern B.C. at low to moderate elevations (MacKinnon et al. 1992, Douglas et al. 1998).

Seed Information

Seed Size: Length: 4.09 mm (3.51 - 4.90 mm).
Width: 0.76 mm (0.50 - 0.96 mm).

Seeds per gram: 2,682 (range: 2,255 - 3,470).

Volume to Weight Conversion: Unknown.

Germination Capacity: At 30°/20° C untreated: 23.3%.
At 25°/15° C untreated: 30.3% (23 - 41%).
stratified: 32.8% (29 – 36%).

Germination Speed: To first germination: 16.0 days.
To 50% potential: 39.9 days.

Figure 84. Seeds of *Arnica chamissonis*. Rule divisions are 0.5 mm.

Seed Longevity: Unknown at present, however Kramer and Johnson (1987) report that seeds of *Arnica* sp. have been found in mature forest seed banks. Link (1993) reports that seeds of *Arnica sororia* Greene are viable for about five years. In our research, seeds of *Arnica chamissonis* retained their viability after storage under cool dry conditions for two years.

Considerations for Growing

Techniques for Seed Production

Seed treatment: Germination tests suggest marginal benefits to stratification; establishment likely better in cool soils (early or late in the growing season).

Soil considerations: Establish on loamy, well-drained rich humus, (pH 7), with a firm seedbed (Richters 2000).

Arnica chamissonis ssp. *foliosa* meadow arnica (continued)

(Techniques for Seed Production, continued)
Stand establishment: Site should be free of all weeds, especially rhizomatous grasses because there are currently no selective herbicides that can be used once plants are growing. In our research, stand establishment from seed is very successful; also establishes well from peat moss plugs sown 12 weeks prior to field planting.
Row spacing (for both plugs and seeds): 60 to 120 cm under dry land conditions, 30 to 90 cm with good irrigation (Smith and Smith 2000); this species will spread vegetatively to quickly form rows several plants wide, hence the recommendation for wide spacing.
Seeding density: 60-100 PLS seeds per linear metre.
Seeding depth: Surface to shallow seeding (Smith and Smith 2000), a light dusting of peat moss will help to keep the seeds in place.
Stand maintenance: Regularly cultivate rows and spot spray with herbicide to keep plot weed free; annual fertilization with low N formulations may extend the life of the plot; stand longevity is 3-5 years. *Arnica chamissonis* is very easy to grow, as its rhizomes quickly fill in the spaces between plants. Vigorous shoot growth results in lodging, however, so high levels of N should probably not be applied.

Harvesting and Seed Processing
Dates of selective harvesting in the Bulkley Valley of northwestern B.C. have ranged from July 7th to October 6th. Watch the plants carefully and harvest seeds as soon as they are ripe. *Arnica chamissonis* seeds are not as prone to dislodging by wind as those of *A. cordifolia*.
Hand clipping: May or may not be suitable, as it is not yet known whether curing will facilitate after-ripening of remaining seeds. Hold the seed heads over bins placed alongside the plants being clipped or place a bag over the seed heads before clipping to minimize seed loss.
Vacuum: Vacuum ripe seed heads selectively as they ripen by placing vacuum intake completely over seed head.
Seed stripper: Not recommended for harvesting this species.
Combine/Thresher settings: Repeated runs at 1241 rpm with 4 mm gap; remove fluff between runs by hand or vacuum.
Seed cleaning: After threshing, remove remaining fluff with shop vacuum; if there are stems and twigs present put through fanning mill screens, fanning mill screen sizes: prescreen 1.2 x 7.1 mm slot; top 1.8 x 12.7 mm slot; bottom blank.
Storage requirements: Cool dry storage (Burton and Burton 2001b).

Considerations for Use in Revegetation

In Alberta, *Arnica chamissonis* is reported to grow on wet to mesic soils (Gerling et al. 1996).
The ability of *Arnica chamissonis* to spread rapidly through rhizomes makes it very useful for erosion control.

Other considerations

Arnica chamissonis has potential as a garden species, though aggressive spreading needs to be contained. It is already commercially available from some specialized seed houses and nurseries.

Arnica chamissonis ssp. *foliosa* (continued) — meadow arnica

(Other considerations, continued)

Both wild and cultivated *Arnica* species are used in as many as 300 drug preparations in Europe and about 20 products in Canada (Small and Catling 2000). The medicinal and pharmaceutical properties of *Arnica chamissonis* remain to be fully explored.

Notes

Arnica cordifolia Hook.
heart-leaved arnica **Family: Asteraceae**

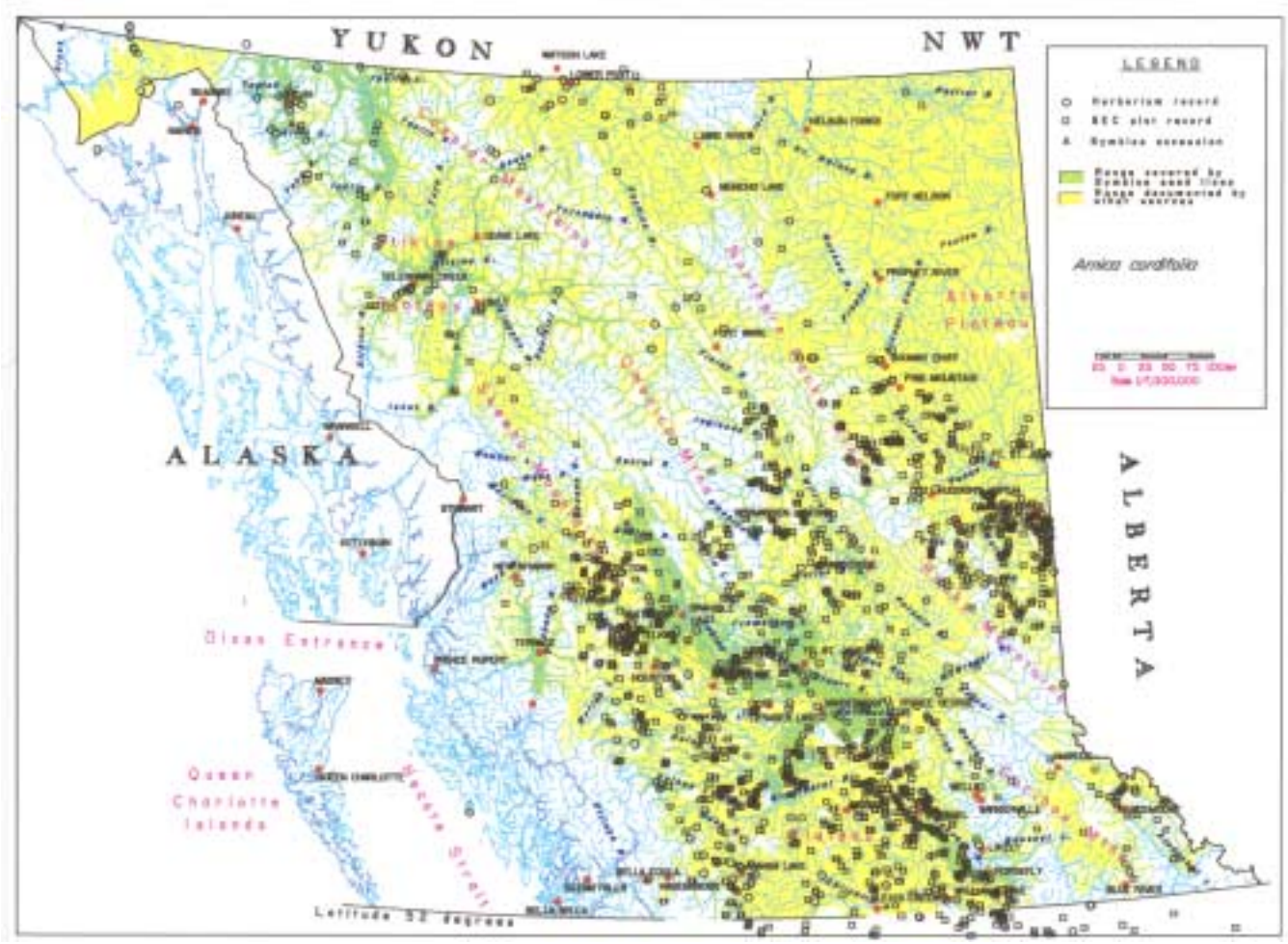

Figure 85. Documented range of *Arnica cordifolia* in northern British Columbia.

Figure 86. Growth habit of wild *Arnica cordifolia*.

Figure 87. *Arnica cordifolia* grown in cultivation, with individual plants inserted in weed cloth holes.

Arnica cordifolia Hook. heart-leaved arnica (continued)

Background Information

Arnica cordifolia occurs in boreal and cool temperate climates and is found north to Alaska, the Yukon and Northwest Territories, east to Saskatchewan and south to South Dakota, New Mexico, Arizona and California (Douglas et al. 1998).

Growth Form: Rhizomatous perennial herb; heart-shaped basal leaves, coarsely toothed to entire, 2-3 pairs of opposite stem leaves; yellow ray and disc flowers; mature plant size is 10–60 cm tall (MacKinnon et al. 1992, Douglas et al. 1998). Rhizomes grow laterally 1–2 cm below the soil surface. Shorter stature, slower growing and not as vigorously rhizomatous as *A. chamissonis*.

Site Preferences: Mesic to dry forest and meadows at low to moderate elevations throughout the northern Interior. Reported to be shade tolerant to shade intolerant (*Stickney 1993, *Steele and Geier-Hayes 1987, MacKinnon et al. 1992, Douglas et al. 1998). It inhabits exposed, moderately dry mineral soils but can occur on a variety of soil types; commonly found in open-canopy coniferous forests on high elevation water-shedding sites, so tends to co-occur with lodgepole pine (*Pinus contorta*) and soapberry (*Shepherdia canadensis*). Occurrence increases with elevation (Klinka 1989). Widely distributed in the ESSF (SNR >A), moderately abundant in the SBS and SBPS (SMR 2-5), on mesic and poorer sites in the BWBS (Beaudry et al. 1999). Recognized as diagnostic of the mv, dk and mc subzones of the ESSF (Coupé et al. 1991).

Seed Information

Seed Size: Length: 6.35 mm (4.34 - 8.60 mm).
Width: 0.71 mm (0.49 - 0.95 mm).

Seeds per gram: 1,991 (range: 1,657 – 3,030).

Volume to Weight Conversion: Unknown.

Germination Capacity: At 30°/20° C untreated: 10.7% (2 - 19%).
At 25°/15° C untreated: 17.4% (12 - 23%).
stratified: 22.7% (22 – 23%).

Symbios results of 2 to 23% germination contrast with those of Romme et al. (1995), who found that nearly all *Arnica cordifolia* seeds were non-viable, with only one seed germinating Out of 650 seeds tested.

Figure 88. Seeds of *Arnica cordifolia*. Rule divisions are 0.5 mm.

Germination Speed: To first germination: 13.1 days.
To 50% potential: 21.9 days.

Seed Longevity: Unknown at present; however, *Kramer and Johnson (1987) report that seeds of *Arnica cordifolia* have been found in mature forest seed banks. Link (1993) reports that seeds of *Arnica sororia* Greene, a similar species, are viable for about five years. In our research, seeds were still viable after three years of storage under cool, dry conditions.

Arnica cordifolia Hook. heart-leaved arnica (continued)

Considerations for Growing

Techniques for Seed Production

Seed treatment: Germination tests suggest that seed stratification is slightly beneficial, and that emergence will be more successful under cool conditions (Burton and Burton 2001b).
Soil considerations: Requires loamy, well prepared soils, firm seedbed.
Stand establishment: Site should be free of all weeds, especially rhizomatous grasses, because there are currently no selective herbicides that can be used once plants are growing. Stands can either be established from rhizomes (Reed 1993), from seedlings started in the greenhouse, or from seed; appears to establish more successfully from seedlings started in a greenhouse.
Row spacing: Unknown; suggest 75-120 cm under dry land conditions, 30-90 cm under irrigation.
Seeding density: Unknown at present; suggest 60-100 PLS per linear metre (Smith and Smith 2000).
Seeding depth: Surface to shallow seeding; a light dusting of peat moss will help to keep the seeds in place.
Stand maintenance: Regularly cultivate rows and spot spray with herbicide to keep plot weed free; annual fertilization with low N formulations may extend life of the plot.

Harvesting and Seed Processing

Dates of selective harvesting in the Bulkley Valley of northwestern B.C. have ranged from June 28th to September 26th. Watch the plants carefully and harvest seeds as soon as they are ripe because they easily dislodge and blow away.
Hand clipping: May or may not be a suitable harvesting method, as the ability for immature seeds to ripen after clipping is unknown. Hold the seed heads over bins placed alongside the plants being clipped or place a bag over the seed heads before clipping to minimize seed loss.
Vacuum: Vacuum ripe seed heads selectively as they ripen by placing vacuum cleaner intake completely over seed head.
Seed stripper: Not recommended for harvesting this species, though presumably could be done with a fine-threaded harvesting head on a uniformly ripened crop.
Combine/thresher settings: Repeated runs at 1241 rpm with 4 mm gap; remove fluff between runs by hand or using a vacuum.
Seed cleaning: Run threshed material through fanning mill screens: prescreen 1.2 x 7.1 mm; top screen 1.8 x 12.7 mm; bottom blank.
Storage requirements: Cool dry storage.

Considerations for Use in Revegetation

Arnica cordifolia is reported to grow on wet to mesic soils in Alberta (Gerling et al. 1996).

Reported to have poor forage value for livestock and to be potentially toxic (Gerling et al. 1996) but *Collins and Urness (1983) report that it is an important constituent of summer diets of mule deer and elk.

Germination in the field has been poor, though, so revegetation from seedlings is recommended if ground cover is required quickly (Burton and Burton 2001b).

Arnica cordifolia is moderately fire resistant, sprouting from surviving rhizomes after fire; also regenerates from wind-dispersed seeds (Reed 1993).

Arnica cordifolia Hook. heart-leaved arnica (continued)

(Considerations for Use in Revegetation, continued)

Arnica cordifolia has low resistance to repeated human trampling (*Cole 1988, *Powell 1988).

* *fide* Reed 1993a.

Other considerations

Arnica cordifolia has good potential for cultivation in woodland gardens (Douglas 1982).

Both wild and cultivated *Arnica* species are used in as many as 300 hundred drug preparations in Europe and about 20 products in Canada (Small and Catling 2000). Medicinal and nutraceutical properties of *Arnica cordifolia* have yet to be fully explored.

Notes

Aster conspicuus Lindl.

showy aster **Family: Asteraceae**

Figure 89. Documented range of *Aster conspicuus* in northern British Columbia.

Figure 90. Growth habit of *Aster conspicuus* in the wild.

Aster conspicuus Lindl. showy aster (continued)

Background Information

Aster conspicuus is found throughout western North America (Reed 1993). Douglas et al. (1998) report that it is found south of 57°N, east to Saskatchewan and south to Wyoming, Idaho and Oregon. MacKinnon et al. (1992) report that it is common throughout the northern B.C. Interior, and is abundant in the southern half of the region (south of 57°N). It is a common interior species on water shedding sites (Klinka et al 1989).

Growth Form: Rhizomatous perennial herb; small basal leaves, thick clasping stem leaves, sand-papery to the touch when mature; blue to violet ray flowers, yellow disk flowers; mature plant size is 30–100 cm tall (MacKinnon et al. 1992, Douglas et al. 1998).

Site Preferences: Moist to dry meadows, forest openings, thickets, and clearings at low to middle elevations. It is reported to be able to maintain and extend itself in a vegetative condition under a closed forest canopy and then flower profusely when the canopy opens up (Breitung 1988). It is reported to be shade-tolerant to shade-intolerant, associated with increased nitrogen availability. Widely distributed in the SBS zone at SMR <6, more narrowly distributed in the BWBS (SMR 3-4) and on dry fertile sites in the SBPS (SMR <5, SNR >A), though rare in the SBPSmc (Beaudry et al. 1999). Identified as a diagnostic species of the dh, dw, dk, mh, and mw subzones of the SBS (Meidinger et al. 1991).

Seed Information

Seed Size: Length: 3.56 mm (2.44 - 4.98 mm).
Width: 0.73 mm (0.41 - 1.01 mm).

Seeds per gram: 2,107 (range: 1,746 - 2,708).

Volume to Weight Conversion: 96.8 g/L at 81.1% purity.

Germination Capacity: At 30°/20° C untreated: 18.4% (6 - 31%).
At 25°/15° C untreated: 8.9% (34 - 44%).
stratified: 51.7% (39 - 65%).

Germination Speed: To first germination: 13.2 days.
To 50% potential: 25.1 days.

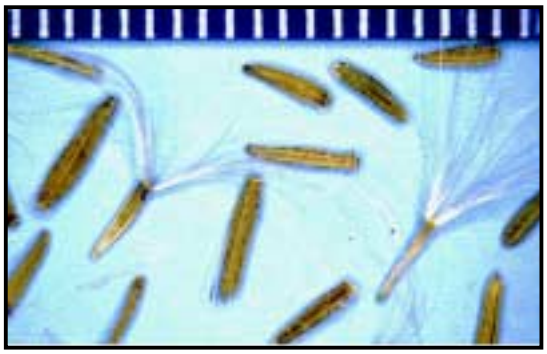

Figure 91. Seeds of *Aster conspicuus*. Rule divisions are 1.0 mm.

Seed Longevity: In our research, seeds of *Aster conspicuus* seeds retained their viability after storage under cool dry conditions for two years.

Considerations for Growing

Techniques for Seed Production

Seed treatment: Higher germination can be achieved with stratification prior to sowing.

Soil considerations: Establish on loamy, well-prepared soils, with a firm seedbed; superior germination under cool conditions suggest importance of sowing very early or late in the growing season.

Stand establishment: Site should be free of all weeds, especially rhizomatous grasses because there are currently no selective herbicides that can be used once plants are growing.

Aster conspicuus Lindl. showy aster (continued)

(Techniques for Seed Production, continued)

Row spacing: 75 to 120 cm under dryland conditions, 30 to 90 cm with good irrigation (Smith and Smith 2000).
Seeding density: Not known at present; 375 PLS seeds per linear metre inferred from recommendations for the similar species, *A. ericoides*.
Seeding depth: Surface to shallow seeding (Pahl and Smreciu 1999); a light dusting of peat moss will help keep the seeds in place.
Stand maintenance: Regularly cultivate rows and spot spray with herbicide to keep plot weed free; annual fertilization with low N formulations may extend life of the plot.

Harvesting and Seed Processing
Dates of selective harvesting in the Bulkley Valley of northwestern B.C. range from August 21st to September 24th. Timing of harvest is important as seed scatters moderately easily.
Hand clipping: May or may not be a suitable method for harvesting, as the ability of unripe seeds to mature after clipping is unknown. Hold the seed heads over bins placed alongside the plants being clipped, or place a bag over the seed heads before clipping to minimize seed loss. To aid cleaning process, pick seeds off each head without clipping stalks.
Vacuum: Vacuum ripe seed heads selectively as they ripen by placing the vacuum cleaner intake completely over seed head; a shop vacuum works best for this species; harvest as soon as seeds ripen because they are easily airborne.
Seed stripper: Not recommended for harvesting this species, though presumably would be suitable if using a soft-threaded harvesting head on a uniformly ripe crop.
Combine/thresher settings: Repeated runs at 1241 rpm with 4 mm gap; can use rotary flail if seed heads are clipped an on long stalks.
Seed cleaning: Put through fanning mill, screen sizes: prescreen 1.2 x 7.1 mm slot; top 1.8 x 12.7 mm slot; bottom blank, then use vacuum separator with speed and suction set low to remove dust and <5% of seeds.
Storage requirements: Cool dry conditions.

Considerations for Use in Revegetation

Aster conspicuus is reported to have good forage value for deer, elk, cattle and domestic sheep (*McLean 1968, *Steele and Geier-Hayes 1993, Gerling et al. 1996).

This species is common in the summer diets of both black bear and grizzly bear (*Holcroft and Herrero 1991).

Aster conspicuus has low resistance to repeated human trampling but recovers rapidly (*Cole 1988).

Aster conspicuus is moderately resistant to fire, and increases rapidly after fire by sprouting from surviving rhizomes (*Crane et al. 1986, *Fischer et al. 1987).

***fide* Reed 1993b.

Other considerations

This attractive and robust plant has potential as an ornamental garden species (Douglas 1995).

***Aster conspicuus* Lindl.** **showy aster**
(continued)

Notes

Aster foliaceous Lindl.
leafy aster **Family: Asteraceae**

Figure 92. Documented range of *Aster foliaceous* in northern British Columbia.

Background Information

Aster foliaceous is found north to Alaska, the Yukon and Northwest Territories, east to Alberta and south to New Mexico, Arizona and California (Hitchcock et al. 1969, Douglas et al. 1998). In British Columbia, it is found in all vegetation zones throughout the southern half of the northern Interior (south of 56°N). Reports that it occurs in the extreme northwest corner of the province (MacKinnon et al. 1992, Douglas et al. 1998) could not be confirmed.

Growth Form: Rhizomatous perennial herb with a short woody stem base; stalked basal leaves, unstalked stem leaves with clasping flanges; rose-purple to blue or violet ray flowers, yellow disk flowers; mature plant size is 10-60 cm tall (MacKinnon et al. 1992).

Site Preferences: Moist to mesic meadows, streambanks, slopes and forests in all vegetation zones and at all elevations (MacKinnon et al. 1992, Douglas et al. 1998).

Aster foliaceous Lindl. leafy aster (continued)

Seed Information

Seed Size: Length: 3.29 mm (2.67 mm - 3.91 mm)
Width: 0.84 mm (0.67 - 0.98 mm)

Seeds per gram: 2,696 (range: 2,578 – 2,814)

Volume to Weight Conversion: 108.0 g/L at 72.2% purity

Germination Capacity: At 30°/20° C untreated: 38.3%
At 25°/15° C untreated: 53.0%
stratified: 73.7%

Germination Speed: To first germination: 6.5 days
To 50% potential: 12.3 days

Seed Longevity: In our research, two year old *Aster foliaceous* seeds had 10% higher germination than seeds grown in the same year, suggesting that some degree of after-ripening or inadvertent stratification may occur in storage.

Figure 93. Seeds of *Aster foliaceous*. Rule divisions are 1.0 mm.

Considerations for Growing

Techniques for Seed Production

Seed treatment: Higher germination can be achieved with stratification prior to sowing.

Soil considerations: Establish on loamy, well-prepared soils with a firm seedbed. Superior germination under cool conditions suggests that sowing very early or late in the growing season would be advantageous.

Stand establishment: Site should be free of all weeds, especially rhizomatous grasses and other persistent species because there are currently no selective herbicides that can be used once plants are growing. Stands can be established from seedlings started in the greenhouse or from seed.

Row spacing: 75 to 120 cm under dryland conditions, 30 to 90 cm with good irrigation (Smith and Smith 2000).

Seeding density: Unknown at present; recommendation of 375 PLS seeds per linear metre based on the similar species, *A. ericoides*.

Seeding depth: Surface to shallow seeding (Pahl and Smreciu 1999); a light dusting of peat moss will help keep the seeds in place.

Stand maintenance: Regularly cultivate rows and spot spray with herbicide to keep plot weed free; annual fertilization with low N formulations may extend the life of the plot.

Harvesting and Seed Processing

Dates of selective harvesting in the Bulkley Valley of northwestern B.C. have ranged from August 16th to September 21st. Seed scatters moderately easily.

Hand clipping: May or may not be a suitable method for harvesting, as the ability of immature seeds to ripen after clipping is unknown. Hold the seed heads over bins placed alongside the plants being clipped, or place a bag over the seed heads before clipping to minimize seed loss.

Vacuum: Vacuum ripe seed heads selectively as they ripen by placing the vacuum cleaner intake completely over seed heads; a shop vacuum works best for harvesting this species; harvest as soon as seeds ripen, as they are easily airborne.

Seed stripper: Not recommended for harvesting this species.

Combine/thresher settings: Repeated runs at 1241 rpm with 3 mm gap; can use rotary flail to dislodge all remaining seeds from seed heads if harvested with long stalks.

Aster foliaceous Lindl. leafy aster (continued)

(Harvesting and Seed Processing, continued)

Seed cleaning: Put through fanning mill, screen sizes: prescreen 1.2 x 7.1 mm slot; top screen 1.8 x 12.7 mm slot; bottom blank.
Storage requirements: Cool dry storage (Link 1993).

Considerations for Use in Revegetation

There is little information available about *Aster foliaceous*. However, the following is reported about two similar species, *Aster ericoides* (Pahl and Smreciu 1999) and *Aster laevis* (Sullivan 1992):

Aster ericoides and *Aster laevis* are both considered palatable to grazing by cattle in the early stages of growth (Sullivan 1992, Pahl and Smreciu 1999).

These *Aster* species increase in response to bison grazing on the prairies (Pahl and Smreciu 1999).

These *Aster* species can spread quickly in open areas with little competition (Pahl and Smreciu 1999).

Aster laevis sprouts well from rhizomes after being top-killed by fire (Sullivan 1992).

Aster laevis is recommended in seedings and plantings for rehabilitation or restoration of native mixed-grass and tallgrass prairies (*Moyer and Smoliak 1987, *Nuzzo 1978, *Woehler and Martin 1978).

* *fide* Sullivan 1992.

Other considerations

Some *Aster* species have ornamental potential (Douglas 1995).

Notes:_____

Aster foliaceous Lindl. leafy aster (continued)

Notes

Other Plant Families

Allium cernuum Roth var. *cernuum*

nodding onion **Family: Lilaceae**

Figure 94. Documented range of *Allium cernuum* in northern British Columbia.

Figure 95. Growth habit and flowers of *Allium cernuum* in cultivation.

Allium cernuum Roth var. *cernuum* nodding onion (continued)

Background Information

Allium cernuum is found south of 56°N in British Columbia, ranging from the Pacific Coast to the dry Interior, the Kootenays and the Cariboo (Turner 1997). In the rest of North America it ranges east to Ontario, south to Georgia, Texas, and northwest to Wyoming, Utah, Idaho and Oregon (Douglas et al. 2001a). Only the one variety, *A.c.* var. *cernuum*, is described for B.C. (Douglas et al. 2001a).

Growth Form: Grows from usually clustered faint pink bulbs; slender stems; several grass-like flat or channeled leaves; numerous pink to rose-purple bell-shaped flowers in a nodding umbrella-shaped cluster; smells like onion; mature plant size is up to 50 cm tall (MacKinnon et al. 1992, Douglas et al. 1994).

Site Preferences: Found in the southern half of the northern Interior of B.C. to 55 ° N in dry open woods, exposed grassy plains, rocky crevices and sandy soils at low elevations (MacKinnon et al. 1992, Douglas et al. 2001a). Reported to be shade-intolerant (Klinka et al. 1989, Beaudry et al. 1999). In northern B.C. this species is found on medium to very rich xeric and subxeric sites in the SBS and very poor to very rich xeric and sub-xeric sites in the SBPSmk, on very poor to medium xeric sites in the SBPSmc, and medium to rich xeric and sub-xeric sites in the SBPSx or SBPSd subzones (Banner et al. 1993, Beaudry et al. 1999).

Seed Information

Seed Size: Length: 2.60 mm (2.05 - 3.03 mm).
Width: 1.72 mm (1.36 - 2.04 mm).

Seeds per gram: 348 (range: 313 - 381).

Volume to Weight Conversion: Unknown.

Germination Capacity: At 30°/20° C untreated: 42.8% (12 – 74%).
At 25°/15° C untreated: 19.8%.
stratified: 26.0%.

Germination Speed: To first germination: 14.5 days.
To 50% potential: 48.6 days.

Seed Longevity: In our research, seeds retained their viability for two years after storage under cool dry conditions.

Figure 96. Seeds of *Allium cernuum*. Rule divisions are 1.0 mm.

Considerations for Growing

Techniques for Seed Production

Seed treatment: Untreated seeds germinate best in warmer soils; in cooler soils cold-moist stratification may be beneficial (Young and Young 1990). Gerling et al. (1996) say that scarification may be beneficial.

Soil considerations: Establish on a loamy, moist well-prepared firm seedbed.

Stand establishment: Site should be free of all weeds, especially rhizomatous grasses because selective herbicides cannot be used once plants are growing. Can be established from seed or bulbs.

Allium cernuum Roth var. *cernuum* nodding onion (continued)

(Techniques for Seed Production, continued)

Row spacing: Unknown; suggest 75 to 120 cm under dryland conditions, 30 to 90 cm with good irrigation.
Seeding density: Unknown at present; suggest 60-100 PLS seeds per linear metre (Smith and Smith 2000)
Seeding depth: Shallow with light dusting of peat moss to hold seed in place.
Stand maintenance: Regularly cultivate rows and spot spray with herbicide to keep plot weed free; stand life 2–3 years (Pahl and Smreciu 1999); annual fertilization with low N formulations may extend the life of the plot.

Harvesting and Seed Processing
Dates of selective harvesting in the Bulkley Valley of northwestern B.C. have ranged from September 18th to September 26th. Seeds shatter moderately easily.
Hand clipping: Use sharp hand clippers. Hold the seed heads over bins placed alongside the plants being clipped or place a bag over the seed heads before clipping to minimize seed loss. Do not allow seed capsules to become over-ripe or they will dehisce before harvest and you will lose many seeds. Plastic between rows is recommended so dehisced seeds can be salvaged.
Vacuum: Not recommended.
Seed stripper: Unknown suitability at present.
Combine/thresher settings: 885 rpm with 4 mm gap. Most seeds fall from seed heads while drying.
Seed cleaning: Put through vacuum separator with speed set high and suction set to low to remove dust and <5% of seeds.
Storage requirements: Cool dry conditions.

Considerations for use in revegetation

Gerling et al. (1996) report that *Allium cernuum* has fair forage value for livestock.

Reported to grow on wet to mesic soils in Alberta (Gerling et al. 1996).

Other considerations

May have potential as a specialty health food (Marles et al. 2000).

Can be used as a fresh or dry flavouring for food. First Peoples of British Columbia have historically used *Allium* spp. (Turner 1997).

Allium cernuum and other wild onion bulbs may be confused with *Zigadenus venenosus* (death camas), so care should be taken when harvesting them. The best distinction is the characteristic onion odour present in the *Allium* species (Turner 1997).

Allium cernuum* Roth var. *cernuum **nodding onion (continued)**

Notes

Collinsia parviflora Dougl. *ex* Lindl.
small-flowered blue-eyed Mary **Family: Scrophulariaceae**

Figure 97. Documented range of *Collinsia parviflora* in northern British Columbia.

Figure 98. A dense stand of *Collinsia parviflora* plants that voluntarily emerged from the seed bank of an old hay field after it was cultivated.

Collinsia parviflora Dougl. *ex* Lindl. small-flowered blue-eyed Mary (continued)

Background Information

Collinsia parviflora is an annual species (the only one treated in this manual), found north to Alaska and southern Yukon, east to Ontario, and south to Pennsylvania, Michigan, South Dakota, New Mexico, Arizona and California. It is common in B.C., except in the northeast (Douglas et al. 2000).

Growth Form: Annual herb from a tap root; opposite smooth or minutely hairy leaves, purplish underneath; terminal cluster of short-stalked flowers, 2 lipped; the upper flower lip is two-lobed, white; the lower flower lip is three-lobbed, blue; mature plant size is 5 - 50 cm tall (Douglas et al. 2000).

Site Preferences: Moist to dry grassy slopes, mossy rock outcrops, forest glades and open forests at low to middle elevations (Douglas et al. 2000). In coastal B.C. it is reported to be shade-intolerant, found on very dry to moderately dry nitrogen-medium soils, including open forests on very shallow soils (rock outcrops and cliffs) and meadow-like communities on water-shedding sites. This species is considered characteristic of moisture-deficient sites, and its occurrence appears to increase with increasing temperature (Klinka et al. 1989). *Collinsia parviflora* tolerates a minimum of 406 mm and a maximum of 1270 mm of annual precipitation; it can tolerate minimum temperatures to -36°C (NRCS 2002).

Seed Information

Seed Size: Length: 1.64 mm (1.22 - 1.94 mm)
Width: 1.12 mm (0.84 - 1.40 mm)

Seeds per gram: 1,174 (range: 904 - 1,449)

Volume to Weight Conversion: 758.3 g/L at 87.9% purity

Germination Capacity: At 30°/20° C untreated: not tested
At 25°/15° C untreated: 24.9%
(3 - 49%).
stratified: 5.0%
(2 – 8%).

Germination Speed: No data available.

Seed Longevity: Unknown; probably quite long, as it has emerged from the seed bank of agricultural soils maintained in hay production for decades.

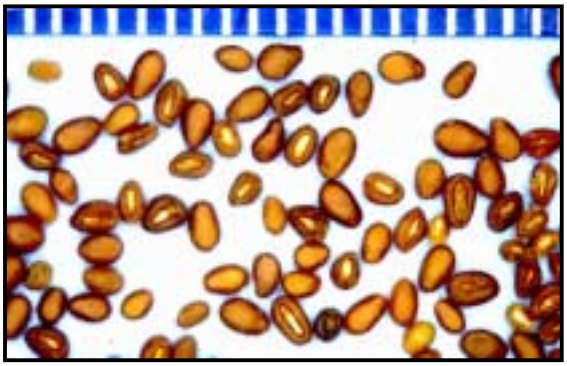

Figure 99. Seeds of *Collinsia parviflora*. Rule divisions are 1.0 mm.

Considerations for Growing

Techniques for Seed Production

Seed treatment: Stratification apparently inhibits germination, at least under cool conditions.
Stand establishment: Requires loamy, well-prepared soils, firm seedbed; site should be free of all weeds, especially rhizomatous grasses because selective herbicides cannot be used once plants are growing; sow early in the year as seeds seem to germinate better under cool conditions.
Row spacing: Unknown; suggest 75-120 cm under dryland conditions, 30-90 cm under irrigation.
Seeding density: Unknown at present; suggest 60-100 PLS per linear metre (Smith and Smith 2000).

Collinsia parviflora Dougl. *ex* Lindl. small-flowered blue-eyed Mary (continued)

(Techniques for Seed Production, continued)

Seeding depth: Surface to shallow seeding; a light dusting of peat moss will help to keep the seeds in place. This species may be slow to establish from seed, as its dormancy mechanism appears to be complex; establishment from greenhouse-propagated plugs may be more reliable, though will be relatively expensive relative to seed yield because propagation has to be repeated annually.
Stand maintenance: Regularly cultivate rows and spot spray with herbicide to keep plot weed free. Since this is an annual species, plots should be retilled annually. If any seed drops before harvesting (which is highly likely), the same plot can often be used year after year for *Collinsia* seed production. Response to fertilization is unknown.

Harvesting and Seed Processing:
The date of selective harvesting in the Bulkley Valley of northwestern B.C. have been as early as July 30th. Seed heads of this species shatter moderately easily, dehiscing when ripe.
Hand clipping: Use sharp hand clippers. Hold the seed heads over bins placed alongside the plants being clipped or place a bag over the seed heads before clipping to minimize seed loss. Do not allow seed capsules to become over ripe or they will dehisce before harvest and you will lose many seeds. Plastic between rows is recommended so dehisced seeds can be salvaged.
Vacuum: Suitability unknown at present.
Seed stripper: Suitability unknown at present.
Combine/thresher settings: 1850 rpm with a 1-2 mm gap.
Seed cleaning: After threshing, run a through fanning mill using the following screen configurations: prescreen 1.8 x 12.7 mm; top screen 1.2 x 7.1 mm; bottom screen 1.2 mm square. Run through vacuum separator at medium suction to remove dust and chaff.
Storage requirements: Cool dry conditions, though seeds of this species are apparently tolerant of a wide range of environmental conditions.

Considerations for Use in Revegetation

Collinsia parviflora has higher germination at lower temperatures, so late fall or early spring sowing is recommended.

Collinsia parviflora has possible use as a cover crop, because this annual species grows quickly, flowers early, and has shallow roots that can provide green-up and erosion control with minimal competition with perennial species. Emergence has been spotty in field trials, however, indicating that we do not fully understand the dormancy mechanisms in the seed of this species.

Until we can better utilize its properties as an annual, inclusion of this species in a seed mixture is generally for diversity, and for its long-lived seeds that may be important constituents of the seed bank at some time in the future.

Other considerations:

Collinsia parviflora has a delicate blue flower that grows easily, so this species has possible ornamental value.

Collinsia parviflora Dougl. _ex_ Lindl. small-flowered blue-eyed Mary (continued)

Notes

Dryas drummondii Richards. *ex* Hook.
yellow mountain-avens **Family: Rosaceae**

Figure 100. Documented range of *Dryas drummondii* in northern British Columbia.

Figure 101. Growth habit of *Dryas drummondii* mats in cultivation; note sand rooting medium.

Figure 102. Close-up of cultivated *Dryas drummondii* in flower.

Dryas drummondii Richards. *ex* Hook. yellow mountain-avens (continued)

Background Information

Dryas drummondii is found north to Alaska and the Northwest Territories, south to Oregon and east to Newfoundland. It is common throughout B.C. east of the Coast-Cascade Mountains but rare west of these mountains (Douglas et al. 1999). Three varieties are recognized (Douglas et al. 1999), which we do not distinguish, though most of our material appears to be *D.d.* var. *drummondii*. This species has been the subject of numerous studies in which its role as a colonizer and nitrogen fixer on recent glacial moraines has been documented (Crocker and Major 1955, Schoenike 1958, Lawrence et al. 1967, Chapin et al. 1994, Kohls et al. 1994).

Growth Form: Forms extensive continuous mats, roots forming symbiotic nodules with the nitrogen-fixing actinomycete, *Frankia* (Kohls et al. 1994); low dwarf shrub from long woody base, alternate evergreen leaves, woolly hairy underneath, solitary flower on leafless woolly-hairy stalks, yellow corollas, dandelion-like fluff of seeds; mature plant size is 15 - 25 cm tall (Hardy 1989, Kohls et al. 1994, Douglas et al. 1999). Tolerates a minimum of 355 mm and a maximum of 1016 mm annual precipitation; can tolerate minimum temperatures to -42°C (NRCS 2002).

Site Preferences: A pioneer species commonly found on gravel bars, glacial moraines, rocky slopes, streamside, roadside and alpines areas north of 54°N (MacKinnon et al. 1992). In Alberta it is reported to grow on coarse textured mesic to dry soils, and to be tolerant of drought and alkaline conditions (Gerling et al. 1996).

Seed Information

Seed Size: Length: 9.63 mm (5.44 - 16.42 mm)
Width : 2.07 mm (1.25 - 3.39 mm)

Seeds per gram: 1,940 (range: 1,837 – 2,244)

Volume to Weight Conversion: 101.5 g/L at 45.0% purity

Germination Capacity: At 30°/20° C untreated: 35.5% (9 - 65%)
At 25°/15° C untreated: 70.3% (58 - 82%)
stratified: 54.8% (22 – 88%)

Germination Speed: To first germination: 16.6 days
To 50% potential: 40.7 days

Seed Longevity: three to five years (Wick et al. 2001)

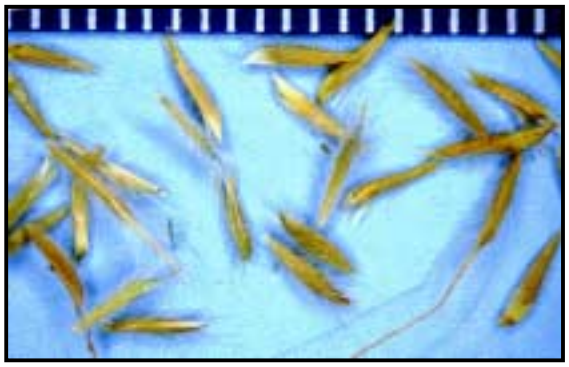

Figure 66. Seeds of *Dryas drummondii*, with most plumes removed. Rule divisions are 1.0 mm.

Considerations for Growing

Techniques for Seed Production

Seed treatment: No apparent benefit to stratification; untreated seed germinates best in cooler soils. *Stand establishment*: Establishes best on very sandy or gravelly, loose moist soil; roots rotted and plants died in Symbios Research plots consisting of loamy soil and no provisions for drainage. Site should be free of all weeds, especially rhizomatous grasses, because selective herbicides cannot be used once plants are growing. We recommend establishing seedlings in a greenhouse first, and then transplanting them out to seed increase plots.

Dryas drummondii Richards. *ex* Hook. yellow mountain-avens (continued)

(Techniques for Seed Production, continued)

Row spacing: Unknown; suggest 75-120 cm under dryland conditions, 30-90 cm under irrigation.
Seeding/planting density: Unknown at present; suggest 60-100 PLS per linear metre (Smith and Smith 2000).
Seeding depth: Surface to shallow seeding; a light dusting of peat moss will help to keep the seeds in place; tends to slow to establish from seed outdoors, establishment from plugs will be faster.
Stand maintenance: Regularly cultivate rows and spot spray with herbicide to keep plot weed free. Annual fertilization with high P and K (very low N) formulations may extend the life of the plot, but mats tend to naturally die back at their center regardless. Maximum seed production may require stand renewal in 5-7 years.

Harvesting and Seed Processing:
Extensive, nearly pure wild stands of this species can be found on gravel bars and low terraces of river floodplains of northern B.C. Collecting seed from the wild may be more efficient than growing it in cultivation for seed production.
Dates of selective harvesting of cultivated stands in the Bulkley Valley of northwestern B.C. have ranged from July 10th to August 2nd. This species holds onto its seed well, unless it is windy.
Hand clipping: *Dryas drummondii* can be collected easily by hand, as the fluffy seeds pull easily from the plant; clipping of entire stalks while still slightly green appears to be acceptable, as seeds can mature somewhat if dried in the sun.
Vacuum: Uniformly ripe seeds can be efficiently harvested with a shop vacuum by placing hose cone directly over mature seed heads.
Seed stripper: Suitability untested, but expected to be good. Seed could possibly be collected with a seed stripper from wild populations, often found as relatively pure stands on river floodplains.
Combine/thresher settings: 1850 rpm with a 1-2 mm gap.
Seed cleaning: Run through rethresher 12 to 15 times, removing fluff each time. Then run through a fanning mill with the following configurations: prescreen 1.2 x 7.1 mm; top screen 1.8 x 12. 7 mm; bottom screen blank.
Storage requirements: Cool dry conditions; Wick et al. (2001) suggest storing the seed at 0^{o}C under low humidity in sealed containers.

Considerations for Use in Revegetation

Dryas drummondii is a nitrogen fixer so grows well on poor soil and could provide ground cover at poor, gravelly or lithic sites (Chapin et al. 1994, Kohls et al. 1994).

Well developed *Dryas* mats create seedbed conditions favourable to establishment of trees such as *Abies lasiocarpa*, *Picea engelmannii* and *Populus trichocarpa* (Schoenike 1958, Blundon et al. 1993).

Mats of established *Dryas* help retain organic matter and moisture (Blundon et al. 1993).

This species is a pioneer on recently deglaciated sites (Hardy 1989, Crocker and Major 1955, Kohls et al. 1994), so is well-adapted for revegetating gravel pits and lithic minespoils at low elevations throughout the north, so long as moisture is not limiting.

Dryas drummondii has proven slow to establish in the field from seed, but once established will last 20 to 30 years until shaded out (Hardy 1989).

Dryas drummondii Richards. *ex* Hook. yellow mountain-avens (continued)

(Considerations for Use in Revegetation, continued)

This species is reported to have low tolerance to drought, medium tolerance to fire and medium fertility requirements (NRCS 2002).

Dryas drummondii apparently has medium palatability to browsing animals and low palatability to grazing animals, with low protein potential (NRCS 2002).

Other considerations:

Dryas drummondii is a pretty, mat-forming dwarf shrub so has possible ornamental and landscaping value, especially in rock gardens and as a ground cover on gravelly areas.

Notes

Epilobium latifolium L.
broad-leaved willowherb **Family: Onagraceae**

Figure 104. Documented range of *Epilobium latifolium* in northern British Columbia.

Figure 105. Growth habit and flowers of *Epilobium latifolium* growing in the wild. Note the sand, gravel and cobble substrate.

Epilobium latifolium L. broad-leaved willowherb (continued)

Background Information

Epilobium latifolium is a circumpolar species found frequently throughout British Columbia especially northward (although rare on the Queen Charlotte Islands and adjacent mainland), north to Alaska, the Yukon and Northwest Territories, east to Quebec, south to South Dakota, Colorado and California, and throughout Eurasia (Douglas et al. 1999). It is also known as *Chamaenerion latifolium* (L.) Sweet, the name that is usually applied to this species in Europe.

Growth Form: Low growing herb with a woody base; fleshy alternate leaves with white-grey bloom; large showy pink to rose-purple flowers; mature plant size: 5-30 cm tall (MacKinnon et al. 1992, Douglas et al. 1999).

Site Preferences: Sandy soils and gravel bars, streamside, and on dry subalpine talus or scree slopes in the montane to alpine zones, usually at higher altitudes (Hardy 1989, MacKinnon et al. 1992, Douglas et al. 1999). In coastal B.C., this species is reported to be very shade-intolerant and is found up to alpine tundra, scattered to plentiful on nitrogen-rich water receiving sites especially along intermittent streams, often found in early seral communities on exposed mineral soil (Klinka et al. 1989, Chapin et al. 1994). It can tolerate wide pH range (Hardy 1989). Klinka et al. (1989) report that its occurrence increases with latitude.

Seed Information

Seeds borne with tufts of hairs in elongated capsules.

Seed Size: Length: 1.58 mm (1.15 - 1.84 mm)
Width: 0.55 mm (0.34 - 0.77 mm)

Seeds per gram: 10,489 (range: 7,782 - 13,004)

Volume to Weight Conversion: Unknown

Germination Capacity: At 30°/20° C untreated: 53.0% (44% - 62%)
At 25°/15° C untreated: 61.4% (52 - 78%)
stratified: 39.0%

Germination Speed: To first germination: 10.8 days
To 50% potential: 19.3 days

Seed Longevity: Unknown.

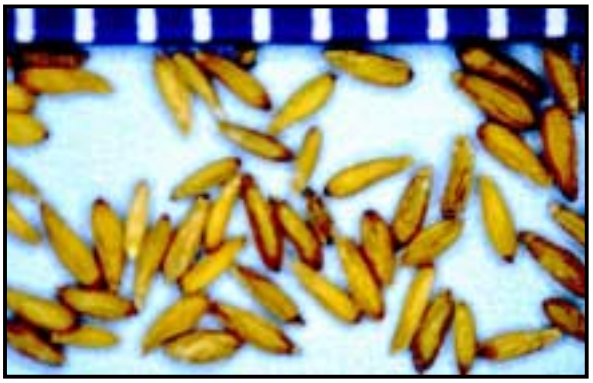

Figure 106. Seeds of *Epilobium latifolium*. Rule divisions are 1.0 mm.

Consideration for Growing

Techniques for Seed Production

Seed treatment: Stratification at 5°C for two months is detrimental, so no pre-germination treatments are recommended.

Soil considerations: Establish on a moist clay loam to sandy firm seedbed (Hardy 1989); gravelly soils seem to be preferred, so long as moisture is available.

Stand establishment: Site should be free of all weeds, especially rhizomatous grasses and other persistent species because there are currently no selective herbicides that can be used once plants are growing. This species can establish in gravelly sandy soils if there is moisture present.

Epilobium latifolium L. broad-leaved willowherb (continued)

(Techniques for Seed Production, continued)

Row spacing: Unknown; suggest 75 to 120 cm under dryland conditions, 30 to 90 cm with good irrigation.
Seeding density: Unknown at present; suggest 60-100 PLS seeds per linear metre (Smith and Smith 2000).
Seeding depth: Surface with light dusting of peat moss to hold seed in place.
Stand maintenance: Regularly cultivate rows and spot spray with herbicide to keep plot weed free; annual fertilization with low N formulations may extend the life of the plot.

Harvesting and Seed Processing
Dates of selective harvesting in the Bulkley Valley of northwestern B.C. have ranged from July 21st to October 2nd. Harvest seed as quickly as possible when ready, because seeds can float away on the wind once capsules ("pods") dehisce (split open).
Hand clipping: Use sharp hand clippers. Harvest individual seed capsules or entire fruiting stalks as the capsule tips start to split. Hold the seed heads over bins placed alongside the plants being clipped or place a bag over the seed heads before clipping to minimize seed loss. Do not allow seed capsules to become over-ripe or they will dehisce before harvest and you will lose many seeds.
Vacuum: Vacuum ripe seed heads selectively as they ripen by placing vacuum intake completely over the ripe heads. Plastic between rows is recommended so dehisced capsules can be salvaged by vacuum as well.
Seed stripper: Not tested, but may be effective so long as wind blows into the hopper during harvesting and some seed loss is anticipated.
Combine/thresher settings: 1241 rpm with 1-2 mm gap until most of fluff is removed; remove fluff after each hopper is put through.
Seed cleaning: Put through fanning mill with the following configurations: prescreen 1.2 x 7.1 mm slot; top screen 1.2 x 1.5 mm slot; bottom blank. Then put through vacuum separator with suction set to low to remove dust, fluff and <5% of seeds. If necessary (or for small quantities), do a final cleaning with a 0.6 mm hand sieve.
Storage requirements: Cool dry conditions.

Considerations for Use in Revegetation

Epilobium latifolium naturally colonizes disturbed sites associated with tailings ponds at selected hard-rock metaliferous mine sites in B.C. (Hardy 1989).

This species is very common on landfill sites in Finland (Hardy 1989).

Growth and establishment of *Epilobium latifolium* is inhibited or delayed in the presence of *Festuca rubra* with >5% cover (Densmore 1992).

In south-central Alaska, Doak (1991) reports that *Epilobium latifolium* had greatly reduced seed production when subjected to attack by its principal herbivore, the lepidopteran insect *Mompha albapalpella.*

Other considerations:

Epilobium latifolium is an attractive plant with potential ornamental value, especially on gravelly soils.

***Epilobium latifolium* L.** **broad-leaved willowherb**
(continued)

Notes

Geum macrophyllum Willd. ssp. *macrophyllum*
large-leaved avens **Family: Rosaceae**

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Figure 107. Documented range of *Geum macrophyllum* in northern British Columbia.

Figure 108. A stand of *Geum macrophyllum* growing in cultivation.

Geum macrophyllum Willd. ssp. *macrophyllum* large-leaved avens (continued)

Background Information

Geum macrophyllum is found north to Alaska and the Northwest Territories, east to Ontario, south to Mexico, and is also found in eastern Asia. It is common throughout B.C. except in the driest parts of the B.C. Interior. Two subspecies are recognized, the coarsely toothed *G.m.* ssp. *perincisum* (Rydb.) Hult. east of the Coast-Cascade Mountains, and the rounded-lobed *G.m.* ssp. *macrophyllum* east of the Coast-Cascade Mountains (Douglas et al. 1999). The plants with which we have been working are all *G.m.* ssp. *macrophyllum*, but subspecies are not always identified so the range in Figure 107 refers to both subspecies and we do not distinguish them further in the discussion below.

Growth Form: Perennial herb with a short rhizome on a stout base; several basal leaves, hairy along the veins, heart to kidney shaped, deeply lobed and blunt tipped; open terminal cluster of saucer shaped flowers with yellow corollas, five petals; mature plant size: 30 to 100 cm tall (Douglas et al. 1999).

Site Preferences: Moist meadows, fields, clearing, roadsides, streambanks and open forests at low to middle elevations throughout the northern Interior (Douglas et al. 1999). This species is reported to be shade-tolerant to shade-intolerant, to be associated with seepage or fluctuating water tables, and to be partial to mineral soil (Beaudry et al. 1999). In northern B.C., it is found on hygric to subhydric, medium to very rich soils in the SBSx or SBSd subzones; on subhygric to subhydric, rich to very rich sites in the SBSm subzones; on hygric to subhydric, medium to very rich sites in the SBSw or SBSv subzones; subhydric medium to very rich sites in the BWBSm subzones; and subhydric medium to very rich sites in the BWBSw or BWBSv subzones; on hygric to subhydric, rich to very rich sites in the SBPSx or SBPSd subzones; and hygric rich to very rich sites in the SBPSmc (Beaudry et al. 1999). It tolerates a minimum of 304 mm and a maximum of 1397 mm annual precipitation; can tolerate minimum temperatures to -36°C (NRCS 2002). In our experience, *Geum macrophyllum* clearly does better on rich sites, though has wide tolerances.

Seed Information

Seed Size: Length: 6.20 mm (4.77 - 7.70 mm)
Width: 1.93 mm (1.48 - 2.31 mm)

Seeds per gram: 2,895 (range: 1,879 - 4,229)

Volume to Weight Conversion: 132.2 g/L at 84.2% purity

Germination Capacity: At 30°/20° C untreated: 65.9 (63% - 69%)
At 25°/15° C untreated: 96.3% (95 - 99%)
stratified: 83.0% (77 - 89%)

Germination Speed: To first germination: 13.2 days
To 50% potential: 17.1 days

Seed Longevity: Unknown.

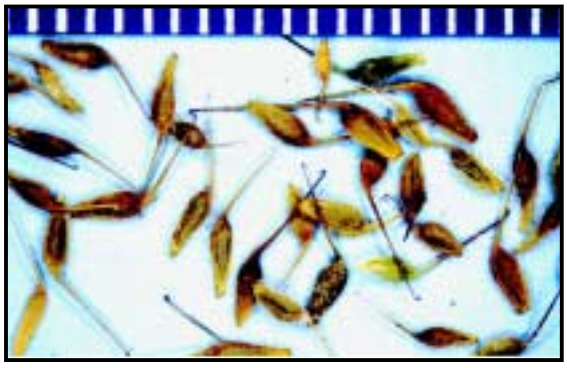

Figure 109. Seeds of *Geum macrophyllum*. Rule divisions are 1.0 mm.

Geum macrophyllum Willd. ssp. *macrophyllum* large-leaved avens (continued)

Considerations for Growing

Techniques for Seed Production

Seed treatment: Stratification at 5°C for two months proved detrimental to germination capacity, so no germination pre-treatment is recommended. Young and Young (1986) also report that seeds do not require pretreatment.

Soil considerations: Requires loamy, well-prepared soils, and a firm seedbed; best germination is achieved on cool soils.

Stand establishment: Site should be free of all weeds, especially rhizomatous grasses because selective herbicides cannot be used once plants are growing; seedlings may be sensitive to drying out (Young and Young 1986).

Row spacing: Unknown; suggest 75-120 cm under dryland conditions, 30-90 cm under irrigation.

Seeding density: Unknown at present; suggest 60-100 PLS per linear metre (Smith and Smith 2000).

Seeding depth: Surface to shallow seeding; a light dusting of peat moss will help to keep the seeds in place; may be slow to establish from seed, so establishment from transplanted plugs is more reliable.

Stand maintenance: Regularly cultivate rows and spot spray with herbicide to keep plot weed free; annual fertilization with balanced formulations may extend the life of the plot.

Harvesting and Seed Processing

Note: This species holds on to its seed very well, and then its hooked appendage holds on to whatever it touches! So don't bring your dog or wear a fluffy sweater when harvesting.

Dates of selective harvesting in the Bulkley Valley of northwestern B.C. have ranged from July 31st to October 16th.

Hand clipping: Use clippers to cut stalks (without leaves) into bins, keeping seed heads aligned in the same direction.

Vacuum: Not recommended for this species.

Seed stripper: Unknown at this time; may work with a suitable harvesting head and optimal ripeness; some curing will likely be required after seed collection.

Combine/thresher settings: Use rotary flail; hold seed heads against flail until seed is removed.

Seed cleaning: Force seed through fanning mill screens in the following configuration: prescreen 1.2 x 7.1 mm slot; top screen 1.8 x 12.7 mm slot; bottom screen position blank.

Storage requirements: Cool dry conditions.

Considerations for Use in Revegetation

Geum macrophyllum needs a moist site, and does best under rich soil conditions, but will establish quickly if those conditions are met.

Basal leaves can provide good ground cover and erosion control, and there is no evidence that any mammals graze on this species.

Other considerations

Geum macrophyllum has a small attractive yellow flower, so has possible ornamental value.

Geum macrophyllum Willd. ssp. _macrophyllum_ (continued) **large-leaved avens**

Notes

Polemonium pulcherrimum Hook. var. *pulcherrimum*

showy Jacob's ladder **Family: Polemoniaceae**

Figure 110. Documented range of *Polemonium pulcherrimum* in northern British Columbia.

Figure 111. *Polemonium pulcherrimum* growing in cultivation.

Polemonium pulcherrimum Hook. showy Jacob's ladder (continued)

Background Information

Polemonium pulcherrimum is found north to Alaska, the Yukon and Northwest Territories, east to southwestern Alberta, and south to Colorado and California. It is common in B.C. east of the Coast-Cascade Mountains. It has also been found at a single location in the Queen Charlotte Islands. Only the variety *P.p.* var. *pulcherriumum* is recognized from B.C. (Douglas et al. 1999).

Growth Form: Tufted basal compound leaves grow from a branched stem base, 10-25 opposite leaflets; terminal head–like clusters of long stalked bell-shaped flowers with blue corollas and yellow centers, rounded petals; mature plant size is 5–35 cm tall (MacKinnon et al. 1992, Douglas et al. 1999).

Site Preferences: Dry rocky or sandy places, roadsides, exposed slopes, rocky slopes at low to high elevations throughout the northern Interior (MacKinnon et al. 1992, Douglas et al.1999). It is reported to be moderately shade-tolerant (Beaudry et al. 1999). In northern B.C., this species is found on xeric to sub-xeric, poor to rich sites in the SBSx or SBSd subzones; on xeric, poor to rich sites in the SBSm subzones; on poor to medium, subxeric sites in the ESSFx or ESSFd subzones; on poor to medium xeric sites in the ESSFw or ESSFv subzones; on xeric to mesic, very poor to medium sites in the SBPSx or SBPSd subzones; and on xeric poor sites in the SBPSmk (Beaudry et al. 1999).

Seed Information

Seed Size: Length: 2.03 mm (1.64 - 2.44 mm)
Width: 0.98 mm (0.81 - 1.17 mm)

Seeds per gram: 1,139 (range: 1,123 - 1,144)

Volume to Weight Conversion: Unknown

Germination Capacity: At 30°/20° C untreated: 79.0% (65 - 3%)
At 25°/15° C untreated: 85.2% (75- 93%)
stratified: 51.2% (22 – 80%)

Germination Speed: To first germination: 6.0 days
To 50% potential: 11.0 days

Seed Longevity: Unknown

Figure 112. Seeds of *Polemonium pulcherrimum*. Rule divisions are 1.0 mm.

Considerations for Growing

Techniques for Seed Production

Seed treatment: As stratification at 5°C for two months resulted in reduced germination capacity (at least when tested at 25°/15°C), no pre-germination treatment is recommended.

Stand establishment: Loamy firm seedbed recommended; site should be free of all weeds, especially rhizomatous grasses, because selective herbicides cannot be used once plants are growing.

Row spacing: Unknown; suggest 75 to 120 cm under dryland conditions, 30 to 90 cm with good irrigation.

Polemonium pulcherrimum Hook. showy Jacob's ladder (continued)

(Techniques for Seed Production, continued)

Seeding density: Unknown at present; suggest 60-100 PLS seeds per linear metre (Smith and Smith 2000).
Seeding depth: Moderately shallow, with light dusting of peat moss or dry soil to hold seed in place.
Stand maintenance: Regularly cultivate rows and spot spray with herbicide to keep plot weed free. Though natural stands typically bloom once and go to seed in early summer, we have found that some aspect of our cultivation protocol (including weed control, watering, and light fertilization with a balanced NPK fertilizer) promoted flowering and seed production all summer long. Annual fertilization with low N formulations may further extend the life of the plot.

Harvesting and Seed Processing
Dates of selective harvesting in the Bulkley Valley of northwestern B.C. have ranged from July 7*th* to October 19*th*, though wild stands frequently have ripe seeds in June. Harvest seeds as soon as capsules turn papery tan brown, as they shatter easily.
Hand clipping: Use sharp hand clippers or scissors. Hold the seed heads over bins or trays placed alongside the plants being clipped or place a bag over the seed heads before clipping to minimize seed loss. Do not allow seed capsules to become over-ripe or they will dehisce before harvest and you will lose many seeds. Placing plastic between rows is recommended so dehisced seeds can be salvaged.
Vacuum: Not recommended for this species. However, since this species dehisces easily from ripe capsules, plastic placed between rows will enable you to harvest lost seeds that were dropped early or are scattered while being harvested by hand clipping or mechanical methods. We recommend that scattered seed be vacuumed from weed cloth immediately after any method of harvesting. These seeds often spoiled when they got wet on plastic, as they would not dry out after becoming covered in a gelatinous coat, perhaps indicative of fungal attack or a property of the seeds themselves.
Seed stripper: Suitability unknown at present; not likely appropriate.
Combine/thresher settings: 1241 rpm with a 3 mm gap.
Seed cleaning: Run through fanning mill with the following configuration: prescreen 1.2 x 7.1 mm slot; top screen 1.5 mm square; bottom screen blank. Then run though vacuum separator at medium suction to remove chaff.
Storage requirements: Cool dry conditions.

Considerations for Use in Revegetation

A useful addition to seed mixes for low nutrient, gravelly and compacted soils, and where a bit of colour is desired.

Polemonium pulcherrimum has a pretty little flower, so has potential for ornamental use.

If grown in cultivation as a horticultural planting, it is worth noting that it can bloom throughout the growing season if the soil is kept fertilized and moist.

***Polemonium pulcherrimum* Hook.** **showy Jacob's ladder**
(continued)

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