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Native Legumes For Reclamation in Alberta

by

A. Smreciu

Wild Rose Consulting, Inc., Edmonton

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DISCLAIMER

This report is intended to provide government and industry staff with up-to-date technical information to assist in the preparation and review of Conservation and Reclamation Approvals, and development of guidelines and operating procedures. This report is also available to the public so that interested individuals similarly have access to the most current information on land reclamation topics.

The opinions, findings, conclusions, and recommendations expressed in this report are those of the authors and do not necessarily reflect the views of government or industry. Mention of trade names or commercial products does not constitute endorsement, or recommendation for use, by government or industry.

REVIEWS

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ABSTRACT

Wild Rose Consulting, Inc. (Edmonton) and the Vegetation Branch of AEC (Vegreville) began a four year project in spring of 1990 to collect, multiply, evaluate, and select native legume species for inclusion in a native seed mixture being developed at AEC for reclamation in the mountains and foothills.

In 1990 and 1991 seeds of the following species were collected from the mountains and foothills of Alberta: *Astragalus alpinus*, *A. americanus*, *A. vexilliflexus*, *Hedysarum alpinum*, *H. boreale*, *H. sulphurescens*, *Lupinus nootkatensis*, *L. sericeus*, *Oxytropis cusickii*, *O. deflexa*, *O. monticola*, *O. sericea*, *O. splendens*, and *O. viscida*. Germination was tested and seedlings were produced in the greenhouse and transplanted into a nursery at Vegreville. Plants were observed for three growing seasons. Data concerning survival, growth and development, and yield were analysed and combined with distribution data. Legumes were then ranked. In the second growing season, plots of potentially desirable species were seeded to increase seed production.

Astragalus alpinus has the best potential for use in reclamation in the mountains and foothills of Alberta up to elevations of 2000 m. It will be useful for establishing a rapid cover on sites but should be used in mixtures containing at least one longer lived, native legume since it appears to be somewhat short-lived.

Both *Oxytropis monticola* and *O. splendens* are also recommended for use in reclamation in the mountains and foothills in the near future. The former can be used up to 1800 m whereas the latter is recommended for up to 1600 m.

Other species with some potential for reclamation include: *Astragalus vexilliflexus*, *Hedysarum boreale*, *Oxytropis sericeus*, and *Oxytropis cusickii*. More work is required for these before they can be released.

To make the recommended species available as soon as possible, seeds will be supplied to a commercial nursery in the spring of 1994. If all goes well, seeds will be available in the fall of 1995.

Each recommended species must be tested at various sites in the mountains and foothills. This will provide users with more complete information regarding where and how to use each species in reclamation and restoration projects in Alberta.

Initial tests of various rhizobial bacteria strains show some potential for improving growth and development of the three selected species. Screening of available rhizobial strains is continuing.

1. INTRODUCTION

The development of an adapted native seed mixture for use in reclaiming disturbances in Alberta's mountains and foothills has long been a priority for the Reclamation Research Technical Advisory Committee (RRTAC). The Reclamation Research Funding Application Procedures Manual of 1978 lists among its priorities for the mountains and foothills the 'development, testing and propagation of native woody and herbaceous species for reclamation.' The Concord Scientific Corporation report on the future reclamation needs in Alberta identifies the 'selection, evaluation, and multiplication of native grass, legume and forb species as the highest priority research topic for the Mountains/Foothills Coal Mine Program' (Smith 1989). The importance of developing a native grass/legume seed mixture for the mountains/foothills was confirmed by the Mountains/Foothills Reclamation Research Program Committee and by RRTAC.

At the request of RRTAC, the Vegetation Branch of the Alberta Environmental Centre (AEC) is developing and testing lines of five alpine grasses for use in reclaiming disturbances (primarily associated with coal mines) in the mountains and foothills of Alberta. During a review of this program by members of RRTAC, Research Management Division (RMD), and Land Conservation and Reclamation Council (LCRC), it was strongly recommended that it be expanded to include legume species with a view to developing a grass/legume seed mixture. The availability of scientific expertise in the Vegetation Branch at AEC and their close collaboration with Wild Rose Consulting, Inc. gave RRTAC a unique opportunity to fulfil a high priority requirement and long-standing goal.

Wild Rose Consulting, Inc. (Edmonton) and the Vegetation Branch of AEC (Vegreville) began a four year project in spring of 1990 to collect, multiply, evaluate, and select native legume species for inclusion in a native seed mixture being developed at AEC for reclamation in the mountains and foothills. The goal was to develop a seed mixture for testing at sites in the mountains and foothills in 1994.

A literature search and review, originally planned as a tool for determining which species to include in the program, was expanded to include information which was required at each phase of the program. A computer-assisted search of the Agricola Abstracts (1970-1990) and the CAB abstracts (1972-1990) (using genus names, and keywords relating to reclamation, revegetation, ecology, reproductive biology and agronomy) was completed in the summer of 1990. Approximately 160 references were located and these formed the basis for the comprehensive literature review. The literature review was updated over the four years of the project. The final review is included in Section 2 of this report. Specific names throughout this report follow Moss (1983).

2. LITERATURE REVIEW

2.1 RECLAMATION WITH NATIVE PLANTS

Native plants are not commonly used in reclamation and revegetation in Alberta except for small disturbances because there is little known about their ecology and reproductive biology. There are 1100 to 1200 species of vascular plants native to the province (Moss 1983) and approximately 70 or 80 are listed in the 'Manual of Species Suitability for Reclamation in Alberta' (Hardy BBT 1989). Of the native plants that are recommended, about 20 to 25 are grasses or graminoids, 34 are shrubs and trees, 8 to 10 are legumes, and only one non-leguminous forb is included. Only a small proportion of these species are being used to their potential in Alberta; many of the plants listed appear to have potential but have not been included in rigorous testing programs to determine their suitability for specific sites. Currah et al. (1983) includes information regarding the biology and cultural requirements of approximately 130 forbs and legumes native to the grasslands of Alberta. To date, very few of these species have been used in reclamation and revegetation. There are no comparable publications for legumes and forbs of other ecoregions of Alberta.

Native plants have several advantages over their agronomic relatives: they are often widely distributed, adapted to establish and grow in a wide variety of habitats, and are genetically diverse (Brown and Johnston 1976). They also add to biodiversity of an area. Species that occur naturally within a specific area are adapted to the local biotic and edaphic conditions, and can be self-perpetuating, with little or no maintenance; the final cover integrates better into the surroundings than do agronomic varieties (Bell and Meidinger 1977). Johnson and Van Cleve (1976) summarized the advantages of using native plants in reclamation in arctic and subarctic North America:

1. seeds have wide genetic variability,
2. the phenology of native plants is adapted to a particular region,
3. native plants are adapted to low nutrient conditions,
4. native plants are cold hardy, and
5. there is no danger of these species becoming weed problems.

Many authors that work in the field of reclamation and revegetation state that the primary reason that native plants are not used more often is that there is a dearth of available seed or nursery stock (Bell and Meidinger 1977; Macyk 1984). There is a readily available supply of agronomic species but agronomic species are not always adapted to the specific sites that need to be reclaimed, particularly the harsh environments at alpine and subalpine elevations, and in the arid regions of the province. Agronomics can also be too adaptive and become persistent and invasive as has been seen with the invasion of Alberta grasslands by smooth brome (*Bromus inermis*) (Romo and Grilz 1990).

Although there are groups and institutions in Alberta (Canadian Parks Service and certain Forest Districts) that have recently mandated the use of native plants for revegetation whenever possible, very few native species are commercially available. Species that are available are most often brought in from other provinces or more commonly from areas in the United States. These may or may not be adapted to specific areas and the use of material from restricted areas may reduce genetic variability of the species in Alberta.

Numerous groups have evaluated shrubs and trees for their reclamation and revegetation potential (Hardy BBT 1989). Some of these are now commercially available. The Alberta Environmental Centre established a program in 1983 to begin to develop native grasses for use in reclamation in the eastern slopes of the Rocky Mountains. They have started to release varieties of these grasses and these will be available for use in reclamation as early as 1994. No extensive work has been carried out with other groups of plants (such as forbs and legumes) although they are also important in the makeup of plant communities.

Agronomic legumes have been tested for use in reclamation in Alberta and are routinely included in reclamation mixtures in Alberta because of their ability to fix nitrogen (Takyi and Islam 1984). They are, however, not always successful (Tomm

1982) since they are not necessarily adapted to the harsh conditions in alpine regions. In a review of revegetation of coal mine disturbances the British Columbia Ministry of Mines and Petroleum Resources (1978) reported that agronomic legumes did not generally survive above the treeline, and they recommended that fertilizers would be necessary for success of grasses since legumes could not be used to supply nitrogen.

Errington (1979) stated that establishment of permanent vegetation cover on large mining disturbances will ultimately depend on the culture of native plants, primarily nitrogen-fixing species. A similar conclusion (that a wider variety of legumes be evaluated for use in reclamation of mine spoils) was reported by Jefferies et al. (1981) in a study of nitrogen accumulation and transfer by legumes established at mine spoils in England.

2.2 NATIVE LEGUMES IN RECLAMATION

There is little information concerning the use of native legumes in reclamation in Alberta or in other parts of North America. Townsend (1974), in a discussion of legume selection and breeding for forage in dryland areas of the Great Plains, reported that one native legume, *Astragalus striatus*, appeared to have some potential for reclamation on sandy soils. Berg (1975), in a report concerning revegetating land disturbances in Colorado, noted that there were no appropriate native legumes species commercially available or in the development stage. Bjugstad and Whitman (1989) reported that several native rangeland legumes from North Dakota, tested for establishment on mine spoils, showed some promise. These included *Petalostemon purpureum*, *Glycyrrhiza lepidota* (both native to Alberta), and *Astragalus ceramicus*. Klebesadel (1971) reported that Alaskan legumes such as *Astragalus harringtonii*, *A. williamsii*, *Oxytropis foliosa*, *Hedysarum alpinum*, and *H. mackenzii (=H. boreale)* excelled in field tests for winter hardiness. The latter two are also native to the mountains and foothills of Alberta.

Native legumes have several characteristics that make them desirable for use in reclamation and revegetation. Several have been reported to form symbioses with nitrogen fixing (rhizobial) bacteria which allow them to grow on nitrogen poor sites such as disturbed soils (Currah et al. 1983). Legumes form mycorrhizal associations with fungal partners that could allow access to normally unavailable forms of phosphorus (Currah and Van Dyk 1986; Redente and Reeves 1981). Many legumes produce long taproots which differ from grass roots in their basic growth morphology (Bassiri et al. 1988) and may have a greater potential for water transport to shoots and food transport to roots, which can increase the amount of water that can be absorbed from greater substrate depths. Some indigenous legumes are pioneer species and have been reported as colonizers of disturbed areas in mountains and foothills in Montana, British Columbia, Alberta and other parts of northern Canada (Baig 1992; Bamberg and Major 1968; Kershaw and Kershaw 1987; Macyk and Skirrow 1984; Meidinger 1981; Russell 1985; Van Zalingen et al. 1989). Many legumes have good competitive ability on preferred sites and are drought and/or shade tolerant (Hardy BBT 1990). Most have long, slender taproots with numerous lateral roots, and some are rhizomatous. Klebesadel (1971) notes that the potential for native Alaskan legumes for revegetation is borne out by the broad range of habitats to which they are suited. Many of these legumes are also native to Alberta.

A publication on habitat development for Alberta Fish and Wildlife (Alberta Energy and Natural Resources 1985) discussed grass-legume mixtures that can be used to improve wildlife habitat and stated that native plants are preferred, however the list of legumes recommended does not include any native species. A comprehensive report by Hardy BBT (1990) on reclamation in alpine regions discussed native Alberta *Hedysarum* species that have been tested for reclamation on disturbances at high elevations. Macyk (1979) briefly notes (in a progress report) that native Alberta legumes that were seeded in revegetation trials at a surface mine in Grande Cache, Alberta 'provided a good cover' and were 'suitable for revegetation purposes'. He used *Hedysarum alpinum*, *Lupinus* spp., and *Oxytropis* spp. collected from a nearby native stand. In later reports, Macyk (1984) and Macyk and Skirrow (1984) noted that seeds of these legumes had relatively low germination and establishment was slower than that of agronomic legumes. No mention was made of dormancies and/or pre-germination treatments such as stratification or scarification. Macyk and Skirrow (1984) and Van Zalingen et al. (1989) reported that several native legumes such as lupin, locoweeds, and alpine hedysarum were colonizing mine sites. Macyk (1984) recommended their use in reclamation if seeds were available.

The 'Manual of Plant Species Suitability for Reclamation in Alberta' (Hardy BBT 1989) includes reclamation-relevant information on the genera *Hedysarum* and *Oxytropis* but information is not species-specific. They do however, include information on particular lupin, pea vine, and wild vetch species (*Lupinus argenteus, Lathyrus ochroleucus*, and *Vicia americana* (= *V. sparsifolia*)). Lesko et al. (1975) and Lesko (1974) included *Vicia americana* in reclamation trials on coal spoils and oil sands tailings in Alberta. Although many of these legumes appear to have potential for reclamation and display many of the qualities that would be desirable for reclamation plantings, none were actually tested and/or evaluated in a systematic and comparative manner, particularly in Alberta (Hardy BBT 1989, 1990). Hardy BBT (1990) concluded that 'very little is known about the performance of individual native plant species on disturbed sites in the alpine in Alberta.... ' and that 'Field trials are required to select plant species appropriate for revegetation of particular sites. In particular, information is needed on:

1. nutrient requirements
2. drought tolerance,
3. germination and establishment requirements, and
4. propagation of native legumes (nitrogen fixers).'

They also indicate a need for identifying nitrogen fixing species of high altitude legumes.

Some legumes provide good forage for ungulates and other wildlife since they have high levels of protein, vitamins, and minerals such as phosphorus and calcium (Klebesadel 1971). Many native legumes are pioneer species on disturbed sites (Baig

1992; Bamberg and Major 1968; Kershaw and Kershaw 1987; Klebesadel 1971; Meidinger 1981; Russell 1984, 1985). Bell and Smyth (1987) in a study of the forage quality of native legumes of the Rocky Mountains in British Columbia, found that these species were used by several different wildlife species and that in general the amount of crude protein in the legumes was two to three times higher than that found in native or agronomic grasses seeded in similar habitats.

The following sections provide a review of information that is available regarding native legumes. We have also included information regarding related, non-native species and their agricultural relatives. This information can be used as a starting point for the some of the steps involved in the species selection process. Legumes are discussed by genus.

2.3 ECOLOGY, BIOLOGY, AND AGRONOMY

2.3.1 *Astragalus*

In Alberta, *Astragalus* is one of the largest legume genera and is represented by 24 species which grow in all ecoregions and almost all habitat types (Moss 1983). At least nine are native to the mountains and foothills. These include: *A. aboriginum, A. alpinus, A. americanus, A. bourgouvii, A. eucosmus, A. miser, A. robbinsii, A. striatus*, and *A. vexilliflexus*. All *Astragalus* species native to Alberta are herbaceous perennials with long taproots or creeping rhizomes. Many of the Alberta species formed rhizobial symbioses and are thought to fix atmospheric nitrogen (Currah et al. 1983). Some species are mycorrhizal; forming associations with vesicular-arbuscular mycorrhizae in the drier regions of the province (*A. bisulcatus, A. crassicarpus, A. drummondii, A. gilviflorus, A. kentrophyta, A. pectinatus, A. striatus*). Dematiaceous surface fungi are associated with alpine species such as *Astragalus alpinus* and *A. vexilliflexus* (Currah and Van Dyk 1986).

In Norway, nitrogen fixation by *Astragalus alpinus* occurs in arctic tundra sites at temperatures of 0°C (although maximum fixation rates were measured at 12 to 15°C) (Granhall and Lid-Torsvik 1975 as cited in Hardy BBT 1989). Similar results were reported from Alaska (Allen et al. 1964), and from high elevations in Utah and Montana (Johnson and Rumbaugh 1986). Nodulation of *A. alpinus* plants from the high arctic tundra (Northwest Territories) was observed by Newcomb and Wood (1986). Nodulation has also been reported for *Astragalus canadensis*, in Oregon (Wood 1971) and in Alaska (Allen et al. 1964), and for *Astragalus eucosmus* in Alaska. The former author also reported that nodulation was affected by soil moisture and temperature.

Astragalus alpinus and *A. striatus* are frequent colonizers of disturbed sites in the mountains and foothills of Alberta whereas *A. eucosmus, A flexuosus*, and *A. frigidus* var. *americanus* are occasional colonizers of these sites (Russell 1985). *Astragalus aboriginum, A. alpinus*, and *A. bourgovii* show good potential for revegetation of calcareous coal mine spoils since they were naturally occurring on calcareous sites at high altitudes in Montana (Bamberg and Major 1968). *Astragalus canadensis* is an early successional stage species in northeastern Oregon (Wood 1971).

Although there is information available concerning the use of *Astragalus cicer* (an introduced species) for reclamation, little or no information is available regarding native *Astragalus* species for this purpose (Hardy BBT 1989).

2.3.1.1 Seed Collection, Cleaning, and Storage. No information was obtained from the literature on collecting wild seeds of *Astragalus* nor on cleaning seeds of native species. Although there are no published investigations regarding appropriate seed storage temperatures for *Astragalus* seeds, storing seeds dry at 3 to 6°C has been used successfully (Smreciu et al. 1988; Ziemkiewicz and Cronin 1981) for numerous Alberta and non-native species. Ralphs and Cronin (1987) report that seeds of *A. lentiginosus* (a non-native) should be stored at 5°C. Seeds of *A. cicer* are reported to retain viability for 12 years at ambient room temperature and low relative humidity (Townsend 1990).

2.3.1.2 Propagation. Although most work was carried out with forage species such as *Astragalus cicer*, or species native to the United States (*A. lentiginosus, A. tennesseensis*), many investigators have reported the need for scarification prior to seed germination (Baskin and Quarterman 1969; Carleton et al. 1971; Hafenrichter et al. 1979; Johnston et al. 1975; Miklas et al. 1987; Townsend and McGinnies 1972a; Ziemkiewicz and Cronin 1981). There were also reports that leachable inhibitors hinder germination of seeds of *Astragalus tennesseensis* and *A. lentiginosus* (Baskin and Quarterman 1969; Ziemkiewicz and Cronin 1981). An investigation of seed germination of some native Alberta *Astragalus* species (*A. bisulcatus, A. drummondii, A. gilviflorus, A. pectinatus*, and *A. striatus)* indicated that they benefit from scarification (Smreciu et al. 1988). There was no information regarding the presence or absence of leachable inhibitors in seeds of these species. In each of these studies, scarification was accomplished by mechanical means (using a scarifier, cement mixer lined with screening, a feed grinder, or by hand with sandpaper), although Miklas et al. (1987) compared acid scarification (using H_2SO_4) to mechanical methods and found no differences. Exact methods need to be established for each species and may vary for seed lots depending on seed size (Townsend and McGinnies 1972a). From field trial results, Carleton et al. (1971) concluded that *Astragalus cicer* seeds lose viability quickly if stored after scarification, however, in a Canada Department of Agriculture publication, Johnston et al. (1975) state that seeds of *A. cicer* could be scarified up to six months prior to seeding. Stratification was not required for germination of any *Astragalus* species studied by Smreciu et al. (1988) although this pretreatment improved germination of some seed lots of *A. pectinatus*.

Nelson and Johnson (1983) reported positive correlations between seed size and germinability for some *Astragalus* species native to Arizona and suggested that larger seeds had a better chance of germinating and the resulting seedlings had a better chance of surviving environmental stresses such as drought. Townsend (1979) in a study of seed weight in relation to initial seedling weight, initial leaf area, and initial leaf weight, concluded that selection for larger seeds of *A. cicer* resulted in rapid seedling growth.

Temperature requirements for germination appear to be variable. Baskin and Quarterman (1969) found that 25°C was the most suitable temperature for germinating seeds of *A. tennesseensis*. *Astragalus cicer* seeds germinate well at 25°C or at alternating 15/25°C, but germination became more temperature dependent with seed age (Carleton et al. 1971). They found that at 7/13°C germination rate was rapid; at either -1/4°C or 21/27°C germination rate was slower but percent germinants was higher. Townsend and McGinnies (1972b) compared germination of species of *Astragalus* at several temperature regimes (5/20°C, 15/25°C, 20/35°C, and at a constant 20°C). They observed that *A. glycyphyllos, A. globiceps, A. dahuricus*, and *A. chinensis* required relatively high temperatures (15/25°C or 20/35°C) for germination. They concluded that total germination of *A. canadensis, A. falcatus, A. flexuosus*, and *A. striatus* was unaffected by temperature, but that germination occurred more quickly at lower temperatures. Germination tests described in the above studies were carried out in the dark, and Ziemkiewicz and Cronin (1981) found that germination of *A. lentiginosus* was not affected by light. In Alberta, wild collected, scarified seeds of *Astragalus* germinated 97 to 100% in the dark (Currah et al. 1983).

In a vegetative propagation trial, Van Dyk and Currah (1982) found that *A. gilviflorus (= A. triphyllus)*, an Alberta grassland species, does not propagate from root cuttings.

2.3.1.3 Nursery Establishment and Production.

Seeding/Inoculation/Transplants. The only information regarding field seeding of *Astragalus* is for the forage crop *A. cicer*. Johnston et al. (1975) stated that the seedbed must be well packed and weed-free, and that seeds should be sown not more than 13 to 19 mm (0.5 to 0.75 in) deep. Townsend (1972) suggested that a seeding depth of 2.5 cm (1 in) was most appropriate. Johnston et al. (1975) also reported that spring seeding was best, but on irrigated land, late summer seedings were also successful. Companion crops are not recommended. Recommended seeding rates for seed production vary according to publication. A rate of 3 to 6 kg/ha (3 to 5 lbs/ac) with 61 to 91 cm (24 to 36 in) row spacings is recommended by Johnston et al. (1975), whereas Bolton (no date) recommended a rate of 1.6 to 2.5 kg/ha (1.5 to 2 lbs/ac) with the same row spacing.

Osmoconditioning of seed lots of cicer milkvetch has limited potential in field establishment but might be beneficial if old or deteriorated seed lots were used (Abernethy 1987).

Although it is recommended that *Astragalus cicer* be inoculated with '*Astragalus*' rhizobium which is available commercially (Johnston et al. 1975), no information is available concerning the use of this inoculant with native Alberta *Astragalus* species.

Maintenance/Weed Control/Diseases and Pests. The only information regarding maintenance, weed control, and pests is for the agronomic species, *Astragalus cicer*. Weed competition can seriously reduce the growth potential of *A. cicer* therefore plots must be kept weed-free (Johnston et al. 1975). No information is available regarding licensed pre- or post-emergence herbicides for any *Astragalus* species.

In a handbook concerning *Astragalus cicer* in Alberta, it is recommended that 224 kg/ha (200 lbs/ac) of phosphorus be used to increase seedling survival and growth (Johnston et al. 1975). These authors also recommend using no nitrogen.

Astragalus cicer can succumb to root-, crown-, and stem-rots but when infections occur in Alberta, they are reportedly light (Johnson et al. 1975). No recommendations regarding avoidance or mitigation are given. Several insects affect *A. cicer* plants including grasshoppers (which cause damage by eating flower buds and seed pods), sweetclover weevils, aphids, thrips, and seed chalcids. Weevils (*Aprion* spp.) have been reported to destroy up to 50% of seed pods of *A. canadensis* in the wild (Wood 1971).

Seed Production/Pollination/Seed Harvest. Although there is little information regarding seed production of native *Astragalus* species, Platt et al. (1974) report that *A. canadensis* seed production increases when plant densities are high.

Many *Astragalus* species were reported to be self-incompatible (or have poor self-compatibility) and required out-crossing for successful seed production (Baskin et al. 1972; Baskin and Quarterman 1969; Green and Bohart 1975; Johnston et al. 1975; Richards 1986, 1987). Mosquin and Martin (1967) reported that the native Alberta species *A. alpinus* might be self-incompatible and that pollination was affected by bumblebees. *Astragalus canadensis* (in Oregon) was pollinated solely by *Bombus* spp. and many early and late ovules aborted due to non-fertilization (Wood 1971). *Astragalus pectinatus* in Alberta was self-incompatible and pollination was affected by Bombus spp., *Osmia* spp., or *Anahophera* spp. (Karron 1989). In Alberta, cicer milkvetch has been reported to be pollinated by 27 species of bees. The native bumblebees are the most efficient pollinators, however honey bees and alfalfa leaf cutter bees can be brought in as pollinators (Richards 1986).

2.3.1.4 Establishment of *Astragalus* at Reclamation Sites. Trials using native legumes in reclamation are scarce and the little information that is available is anecdotal rather than empirical. Selner et al. (1977) state that in an establishment trial at Tent Mountain in southwestern Alberta, spring seeding was best for agronomic legumes including *Astragalus cicer*.

Astragalus eucosmus seedlings tested for survival on disturbed sites at sub-alpine elevations in Alaska by Densmore and Holmes (1987) had good survival after a single growing season in unamended soils and in topsoil amended plots.

Although seeding rates for reclamation have not been established, *Astragalus cicer* planted for forage should be sown at a rate of 11 to 13 kg/ha (10 to 12 lbs/ac) (Alberta Agriculture 1988) and for seed production at 3 to 6 kg/ha (3 to 5 lbs/ac), in rows spaced at 61 to 91 cm (24 to 36 in) and at a depth of 2 cm (0.75 in) (Bolton no date). A companion crop is not recommended.

2.3.1.5 Use of *Astragalus* by Wildlife/Livestock. In a study undertaken in the Rocky Mountains in British Columbia, Bell and Smyth (1987) investigated wildlife use of four *Astragalus* species (*A. alpinus, A. bourgovii, A. robbinsii*, and *A. vexilliflexus*) growing on reclaimed mine spoil. They found that Rocky Mountain bighorn sheep and mountain goats browsed the foliage, stems, pods, and seeds of *A. alpinus* and hoary marmot, golden mantle and Columbian ground squirrels ate the flowers. Flowers, pods, and seeds of *A. bourgovii* were used by bighorn sheep and elk. *A. robbinsii* flowers, pods, and seeds are utilized by bighorn sheep, elk, golden mantle ground squirrels. Elk also ate the foliage and stems of this species. *Astragalus vexilliflexus* flowers were used by golden mantle and Columbian ground squirrels. None of these *Astragalus* species were found to contain toxic levels of alkaloids or selenium. *A. robbinsii* foliage (and sometimes pods) contained aliphatic nitro-toxins at levels that might endanger wildlife (Bell and Smyth 1989). Kufeld et al. (1973) reported that *A. vexilliflexus* was used by mule deer in summer in the Rocky Mountains in the United States.

The effects of animals on *Astragalus* species are not well documented, however Wood (1971) stated that big game will preferentially graze *A. canadensis* in early spring in Oregon.

2.3.2 *Hedysarum*

There are three species of *Hedysarum* native to Alberta: *H. alpinus*, *H. boreale* (includes *H. mackenzii*), and *H. sulphurescens* (Moss 1983). All are native to mountain and foothill regions of the province and *H. alpinum* is found over a wide area that includes the aspen parkland ecoregion. *Hedysarum alpinum* and *H. sulphurescens* have a somewhat upright to erect habit and are sparingly branched, whereas *H. boreale* is slightly more spreading and branched. All have long taproots from woody to semi-woody crowns.

Johnson et al. (1989), in a study of *Hedysarum boreale* from Utah, found that there was sufficient morphological and physiological variation among ecotypes to ensure adaptation of this species to a diversity of sites and that improvement through breeding and selection would be feasible. Willey (1982), in a study of native species for reclamation in northeast British Columbia, concluded that *H. alpinum* might be suitable for reclamation on crushed shale.

All three native *Hedysarum* species have been reported to colonize disturbed sites in the mountains and foothills of Alberta (Russell 1985). Bamberg and Major (1968) also reported that these legumes were found naturally on calcareous sites at high elevations in Montana and may have potential for use in reclamation of these sites. Baig (1992) reported that *H. sulphurescens* was an invader on coal mines in the Rocky Mountains (Alberta) which had been abandoned for 30 to 55 years and he presented data concerning the adaptability and characteristics of this species on waste coal sites. There have been no scientifically rigorous studies published regarding the use of *Hedysarum* species in Alberta, particularly in the mountains and foothills. Hardy BBT (1989) stated in the 'Manual of Plant Species Suitability for Reclamation in Alberta' that these three native species warrant further investigation for their suitability for reclamation.

2.3.2.1 Seed Collection, Cleaning, and Storage. There is little information concerning the collection of *Hedysarum* seeds in the wild except that for *H. boreale*, seeds ripen unevenly (Bassendowski et al. 1989) and therefore seed collection can be labour intensive and time consuming. Seeds of this species can also be difficult to remove from the pods (Bassendowski et al. 1989). Ford et al. (1989) reported that seed production for *H. boreale* can vary among populations although no expected amounts were given.

Information about seed cleaning is limited to the Mediterranean species *Hedysarum coronarium*. Seeds of this species have been successfully cleaned and dehulled using a beet seed decorticating machine that also scarified seeds at the time of cleaning (Watson 1982).

2.3.2.2 Propagation. In *Hedysarum alpinum*, 97 to 100% of wild collected seeds germinated if scarified (Currah et al. 1983). Seed lots of *H. alpinum* collected in grassland regions of Alberta germinated well if seeds were mechanically scarified (using sandpaper). Stratification in combination with scarifying decreased germination (Smreciu et al. 1988).

Redente (1980, 1982) reported that *Hedysarum boreale* germinated under a variety of temperature and light conditions if seeds were scarified. The best germination at a constant temperature was obtained at 15°C and 20°C, whereas the best alternating temperatures were either 15/25°C (8/16 hrs) or 20/15°C (8/16 hrs). He also found that germination was better in dark than in light. Germination was constant under various moisture regimes until the osmotic potential was greater than -7.5 bars at which point germination decreased, indicating a moderate drought tolerance. Hard seeds of *Hedysarum coronarium* germinate if soaked in hot water (60 to 75°C) for one minute prior to sowing (Watson 1982).

Stem (tip and internode) cuttings of *Hedysarum alpinum* had a rooting success of 75 to 100% when placed in vermiculite or sand under mist (Van Dyk and Currah 1982). No work has been done on the feasibility of this method for commercial production. Johnson et al. (1989) found that some ecotypes of *H. boreale* (from Utah) had good rhizome production and might be suitable for stabilizing erodible sites.

2.3.2.3 Nursery Establishment and Production. There is no information on establishment of native *Hedysarum* species in cultivation. Information concerning establishment of *H. coronarium* (native to the Mediterranean with potential as a forage crop in North America) states that seeds should be sown into a well-prepared, fine seed bed (Watson 1982). Seeds can be shallow drilled, or broadcast and harrowed. Douglas (1984) found that seeds should be dehulled prior to sowing to increase germination and produce a uniform stand.

In greenhouse experiments, early establishment of *Hedysarum boreale* could be inhibited by lack of moisture (Johnson et al. 1989). They found that although there were differences among ecotypes, generally the root/shoot ratio increased with a decrease in water availability but root length decreased with a decrease in soil moisture.

Seeding/Inoculation/Transplants. In Alaska, *Hedysarum alpinum* and *H. mackenzii (= H. boreale)* were nodulated (Allen et al. 1964). Johnson et al. (1989) found that *H. boreale* fixes atmospheric nitrogen but there was variation in amounts among ecotypes. They observed that generally the amount of nitrogen produced could be reduced if soil moisture was low. *Hedysarum boreale* infected with rhizobia had increased nitrogen content in the leaves and a greater root biomass whereas infection by mycorrhizal fungi (*Glomus* spp.) increased the phosphorus content and increased the above-ground biomass; plants inoculated with both had the highest amounts of phosphorus and nitrogen (Redente and Reeves 1981). They also observed that a positive relationship between mycorrhizal infection levels and nitrogen fixation rates if plants were inoculated with both rhizobia and mycorrhizal fungi. Plants grew taller, produced more above-ground biomass, and had a greater number of leaves than plants which were uninoculated or inoculated with rhizobia alone. These findings are consistent with those of Carpenter and Allen (1988); after three years (in field studies) plants inoculated with both rhizobia and mycorrhizal fungi had greater above-ground biomass, greater leaf biomass, more leaves, and higher levels of nitrogen and phosphorus than plants receiving only one or no inoculum.

Both *Hedysarum alpinum* and *H. sulphurescens* growing in prairie regions were actively mycorrhizal and grew in association with vesicular-arbuscular mycorrhizae (Currah and Van Dyk 1986).

Maintenance/Weed Control/Diseases and Pests. Since none of the native *Hedysarum* have been grown commercially there is no information regarding the use of herbicides, or other pesticides.

Hedysarum alpinum is susceptible to leaf spotting fungus at flowering time and can also be afflicted with verticillium wilt if inoculated with fungal isolates from alfalfa (Bassendowski et al. 1988).

Seed Production/Pollination/Seed Harvest. In the Yukon, *Hedysarum boreale* was pollinated almost exclusively by bumblebees (Kowalczyk 1973). In Wyoming, this species was pollinated by 37 bee species (Tepedino and Stackhouse 1987), and the authors suggested that if this species is to be grown for seed production in cultivated areas with low native bee populations, importing a pollinating insect would maximize seed production.

Hedysarum sulphurescens flowers in subalpine areas of Alberta are pollinated by bumblebees (*Bombus* sp.) (Young and Owen 1989).

Bassendowski et al. (1989) noted that the erect habit of *Hedysarum alpinum* aids in natural seed dispersal.

2.3.2.4 Establishment of *Hedysarum* at Reclamation Sites. Hardy BBT (1990) states that the three native *Hedysarum* species were considered by Weijer and Weijer (1983) to be suitable for reclamation on disturbances at elevations above 1829 m. This work was not referenced to a particular published study and we have been unable to locate any publication where experimental trials using these species were described; nor were we able to locate any further work that had arisen from these conclusions. *Hedysarum alpinum* seedlings were tested for survival when planted on disturbances at subalpine elevations in Alaska and survival was good on unamended and topsoil amended soils (Densmore and Holmes 1987).

2.3.2.5 Use of *Hedysarum* by Wildlife/Livestock. Ford et al. (1989) reported that *Hedysarum boreale* is non-toxic and palatable and can be used as forage for both livestock and big game. Bassendowski et al. (1989) studied the potential value of *H. alpinum* as a forage legume for the northern Canadian prairies. They concluded that some breeding work would be required to reduce the tannin content for this species to be an acceptable forage crop.

Roots, foliage, stems, and flowers of *Hedysarum alpinum* (grown on coal mine spoil in the Rocky Mountains) were utilized by hoary marmot (Bell and Smyth 1987). They also found that the foliage, stems, and flowers of *H. mackenzii (= H. boreale)* were used by Rocky Mountain bighorn sheep. *Hedysarum sulphurescens* was used by Rocky Mountain bighorn sheep and elk (foliage, stems, and flowers) and by both black and grizzly bears (roots). Pods and seeds of all three species were used by both Columbian and golden mantle ground squirrels. Moderate spring use and heavy summer use of *Hedysarum* by mule deer have been reported in the Rocky Mountains of the United States (Kufeld et al 1973). More particularly, light to moderate summer use of *H. sulphurescens* by mule deer (in Montana) (Kufeld et al. 1973) and elk in summer has been reported (Kufeld 1973).

Hedysarum sulphurescens is an important food source for grizzly bears in northwestern Montana, and adjacent Canada, Alaska, and the Yukon (Edge et al. 1990; Holcroft and Herrero 1984). It is used particularly early in the season when bears emerge from winter dens, and late in the season just prior to entering dens for the winter. Edge et al. (1990) suggested seeding this species on disturbed sites to enhance grizzly bear and big game habitat in Montana.

2.3.3 *Lathyrus*

The genus *Lathyrus* is represented in Alberta by two species; *L. ochroleucus* and *L. venosus*. Both have a widespread distribution in Alberta. They are found in the mountains and foothills of Alberta however, these species grow generally in moist woods and clearings at elevations below alpine and subalpine areas (Moss 1983). Both *Lathyrus* species are considered decreasers in heavily grazed range (Hardy BBT 1990). Although Hardy BBT (1990) included *L. ochroleucus* in the 'Manual of Species Suitability for Reclamation in Alberta' they state that the usefulness of this species remains to be established. Russell (1985) reported that *L. ochroleucus* occurs naturally on disturbed sites in the Alberta mountains and foothills. No published work has been found regarding seed collection, cleaning, and storage, seed germination, vegetative propagation, nursery establishment, and production. In Utah, *Lathyrus* spp. rated poorly for initial rangeland establishment (Plummer et al. 1968).

Lathyrus ochroleucus was grazed heavily in spring and summer by mule deer in the Rocky Mountains of the United States (Kufeld et al. 1973).

2.3.4 *Lupinus*

The genus *Lupinus* is represented in Alberta by five perennial species (*L. argenteus, L. lepidus, L. nootkatensis, L. polyphyllus*, and *L. sericeus*) and one annual species (*L. pusillus*) (Moss 1983). *Lupinus lepidus* and *L. nootkatensis* grow in the mountains and foothills into the sub-alpine to alpine habitats and have restricted distributions whereas *L. sericeus* and *L. argenteus* are more generally distributed in the montane and grassland regions (Moss 1983). *Lupinus polyphyllus* is known from an extremely restricted area in southwest Alberta (Moss 1983).

The status of native lupins for reclamation is relatively unstudied. Lupins have been observed as invaders at disturbed mine sites in Grande Cache, Alberta (Macyk 1977). Bamberg and Major (1968) suggested that three species (*L. argenteus, L. lepidus,* and *Lupinus sericeus)* might be suited for use in reclaiming calcareous mine spoils at high elevations in Montana since these three species are often found growing in calcareous high elevation sites in the mountains of Montana. Johnson and Rumbaugh (1986) reported that *L. argenteus* is an active colonizer species of disturbed sites at high elevations. *Lupinus argenteus* has been recommended for use in high elevation reclamation in Colorado, and transplants of this species survived when planted on a alpine mine site in Montana. Although Weijer (1982) stated that lines of *L. argenteus* have been developed for Parks Canada use in Waterton National Park, no information has been found regarding this development work and no publications are available concerning this or other species of lupins for reclamation in Alberta (Hardy BBT 1989). Kenny (1978) reported that a selection program for *L. argenteus* for reclamation was started at Colorado State University. He also reported that applied research was carried out on 'useful' characteristics. No results (published or unpublished) of this work could be located.

We found no information regarding collecting, cleaning, and storage of seeds of native lupins in our search. Currah et al. (1983) stated that 78 to 80% of wild collected seeds of *L. argenteus* were full and that germination was enhanced by scarification. We were unable to find information concerning nursery establishment, seed production, and harvest of native species of *Lupinus*. There are no exotic lupins grown for forage in Alberta from which we could extrapolate information.

2.3.4.1 Seed Collection, Cleaning, and Storage. Milstein and Milstein (1976) suggest that collection of lupin seed is particularly problematic since seeds on a single stalk do not necessarily ripen at the same time.

2.3.4.2 Propagation. Green tip and internode cuttings, and woody stem cuttings of *Lupinus argenteus* did not root in vermiculite and/or sand under mist in a trial carried out by Van Dyk and Currah (1982).

2.3.4.3 Nursery Establishment and Production.

Seeding/Inoculation/Transplants. In a study of comparative phosphorus requirements of some temperate legumes, Davis (1982) reported that *Lupinus polyphyllus* and *L. arboreus* were able to use sources of phosphorus in soils that were unavailable to other forage legumes such as *Trifolium, Lotus*, and *Medicago* species.

Cultivated lupins in France, grown in neutral or slightly alkaline soils, showed marked improvement in yield and seed content when inoculated with rhizobia. These yield increases were greater than those which were attained by adding up to 160 kg/ha nitrogen fertilizer (Duthion and Amarger 1984).

Nitrogen fixation has been measured from *Lupinus argenteus* plants at high elevations in Utah and Montana (Johnson and Rumbaugh 1986). Johnson and Rumbaugh (1981) found that *L. sericeus* did not form nodules in cultivation when grown on native rangeland in northern Utah and southern Idaho. Hardarson and Jones (1979) found that certain rhizobial strains would increase nodulation and this would be reflected in higher yields. Therefore rhizobia may be a limiting factor in *L. nootkatensis* in Iceland.

Lupinus argenteus growing in grassland regions of Alberta have active vesicular-arbuscular mycorrhizae (Currah and Van Dyk 1986).

Maintenance/Weed Control/Diseases and Pests. *Lupinus sericeus* is susceptible to stem rot (Sinelor and Plantenburg 1979 as reported by Hardy BBT 1990).

Seed Production/Pollination/Seed Harvest. *Lupinus monticola* (a native Montana species) was highly reliant on bumblebee pollinators for seed production (Bauer 1983). *L. argenteus* plants were almost exclusively pollinated by bumblebees (*Bombus* spp.) (Gori 1989).

Lupins were poor seed producers (Klebesadel 1971) and were not adapted to mechanical harvesting methods since seeds ripened sequentially along a single pod (Klebesadel 1971; Milstein and Milstein 1976). Appleyard et al. (1981), in discussing seed of Australia forage lupins, stated that lupin seed is susceptible to internal mechanical damage that results in reduced germination or poor quality seedlings. Damage can be incurred during harvest and handling, or due to insects during seed development.

2.3.4.4 Establishment of *Lupinus* at Reclamation Sites. Hardy BBT (1989), in a summary of several publications, notes that *Lupinus argenteus* would likely be suitable for high elevation revegetation in Alberta, although this conclusion is based on work carried out primarily in the United States.

2.3.4.5 Use of *Lupinus* by Wildlife/Livestock. *Lupinus argenteus* was reported to be used by mule deer in all seasons: light use in winter and spring, moderate use in summer, and heavy use in fall. *L. sericeus* was also used by mule deer; light use in winter, spring, and summer, and moderate use in fall (Kufeld et al. 1973). Kufeld (1973) reports that lupins were a highly valuable fall food source for elk. Moderate use of *L. sericeus* by elk has been reported in winter, spring, and summer.

Lupinus sericeus can cause crooked calf disease if grazed when the plant is young or in an immature seed stage (Keeler 1983).

2.3.5 *Oxytropis*

There are nine species of locoweed (*Oxytropis* spp). native to Alberta; *O. cusickii, O. deflexa, O. jordallii, O. lagopus, O. monticola, O. podocarpa,* *O. sericea*, *O. splendens*, and *O. viscida*. All are perennial and all except *O. lagopus* are found in the mountains and foothills of Alberta. *Oxytropis jordallii* is considered rare in Alberta. *Oxytropis campestris (= O. monticola)*, *O. deflexa*, *O. podocarpa*, *O. sericea*, and *O. splendens* all colonized disturbed sites in the mountains and foothills of Alberta (Russell 1985). Two of these species (*O. campestris* and *O. sericea*) along with *O. viscida* have been suggested as possible candidates for reclaiming calcareous coal mine disturbances in Montana and other northern states (Bamberg and Major 1968). *Oxytropis splendens* and *O. deflexa* were both reported by Baig (1992) to be colonizers of old (30 to 50 years) coal mine spoils in the Rocky Mountains of Alberta, and *O. splendens* was found on spoils as young as two years old. He presented information concerning adaptability and characteristics of these species in coal waste areas. No work has been published concerning the use of these species in reclamation in Alberta.

Willey (1982), in a study of native species for reclamation in northeast British Columbia, concluded that *O. sericea* might be suitable for reclamation on crushed shale from mine sites.

2.3.5.1 Seed Collection, Cleaning, and Storage. Seeds of *Oxytropis riparia* (an agronomic species) should be harvested just as the pods begin to turn brown otherwise seeds will be lost in shattering (Solum et al. 1990).

2.3.5.2 Propagation. Seeds of *Oxytropis sericea* and *O. campestris* (= *O. monticola*) collected in grassland regions of southern Alberta germinated well if seeds were mechanically scarified (Currah et al. 1983). Although soaking seeds of *O. monticola* in hot water increased germination, mechanical scarification resulted in greater number of germinants (Smreciu et al. 1988).

Seeds of the agricultural species *Oxytropis riparia* germinated under a broad range of temperatures (10 to 30°C) but germination was reduced at low temperatures

(5 °C). This species also required scarification (Delaney et al. 1986; Solum et al. 1990) and the latter reference also stated that scarification can be accomplished using a Fersberg scarifier for 20 to 30 seconds. Neither hot water nor acid were as effective as mechanical scarification in removing hard seed coats (Hicks et al. 1989).

Less than 25% of woody stem cuttings of *Oxytropis monticola* and *O. sericea* rooted when placed in vermiculite or sand under intermittent mist (Van Dyk and Currah 1982).

2.3.5.3 Nursery Establishment and Production.

Seeding/Inoculation/Transplants. Samples of *Oxytropis deflexa* collected in Alaska were found to be nodulated by rhizobial bacteria (Allen et al. 1964).

Collections of both *Oxytropis splendens* and *O. viscida* from grassland habitats in Alberta were mycorrhizal (Currah and Van Dyk 1986), whereas alpine collections of *O. jordallii* were associated with dematiacious surface fungi.

Seed Production/Pollination/Seed Harvest. Bauer (1983) found that *Oxytropis campestris* (= *O. monticola*) rely on bumblebee pollinators for seed production.

2.3.5.4 Establishment of *Oxytropis* at Reclamation Sites. *Oxytropis campestris* and *O. deflexa* seedlings were successful on disturbances in a sub-alpine area of Alaska on unamended and topsoil amended soils (Densmore and Holmes 1987).

2.3.5.5 Use of *Oxytropis* by Wildlife/Livestock. Bell and Smyth (1987) observed that in reclamation seedings on coal mine sites in eastern British Columbia, *Oxytropis sericea* and *O. podocarpa* were consumed by various wildlife species. Flowers, pods, and seeds of *O. podocarpa* were used by hoary marmot, and Columbian and golden mantle ground squirrels. Seeds were also a food source for willow ptarmigan. Foliage, flowers, pods, and seeds of *O. sericea* were used by Rocky Mountain bighorn sheep and elk and the foliage was used by mountain goats. Flowers were also eaten by hoary marmot.

Oxytropis campestris and *O. sericea* were moderately used by mule deer in the fall in the Rocky Mountains in the U.S. (Kufeld et al 1973). Light use of *O. splendens* was reported for elk as was heavy spring use of *O. viscida* (Kufeld 1973).

2.3.6 *Vicia*

There is only one species of *Vicia* in Alberta; *V. americana*. This species is found in various habitats in all areas of the province (Moss 1983) and is highly variable (Hardy BBT 1989). It is palatable, makes good forage (decreases with grazing) and is consumed by mule deer, elk and other small animals (Hardy BBT 1989; Kufeld 1973; Kufeld et al. 1973). The use of this species for reclamation has not been extensively studied in Alberta. *Vicia americana* survived for at least two years when it was seeded on coal spoil in Luscar, Alberta (Lesko et al. 1975) but it was unsuccessful on oil sand tailings in northern Alberta (Lesko 1974). Hardy BBT Limited (1989) reported that there have been successful trials with this species in alpine regions of British Columbia. No information concerning agronomy and cultivation of this species is available.

2.4 CONCLUSION

From this review of the literature it is apparent that there is a dearth of information regarding native legumes; their biology, their reproductive systems, their ecology, and especially their use in reclamation in Alberta and elsewhere. Information available is primarily for non-native, forage (agronomic) species. Few studies have focused on the use of indigenous plants in reclamation for Alberta.

As disturbances increase in the mountains and foothills of Alberta, and as the demand for increased use of native species continues there is a desperate need for sound scientific data regarding the success of native legumes in reclamation trials on disturbed sites in the mountains and foothills, and sound experimental results comparing the success of native legumes with non-native legumes which are currently being recommended and used. Further, legumes should be tested in mixtures of other plants such as grasses and forbs since they will be ultimately used in this way.

3. METHODS

To determine which genera were to be included in the program, information on native legumes was assembled from numerous publications on the flora of Alberta, the Rocky Mountains, and plains and foothills (Cormack 1977; Currah et al. 1983; Hitchcock and Cronquist 1973; Kuijt 1983; Moss 1983; Scotter and Flygare 1986; Taylor 1974; Vance et al. 1984). Genera were considered if they were: (i) widely distributed, and (ii) occurred in a range of habitat types in the Rocky Mountains and foothills. The four genera considered were *Astragalus* (milkvetches), *Hedysarum* (sweetbrooms), *Lupinus* (lupins), and *Oxytropis* (locoweeds). The next step was to eliminate species of these genera which would be inappropriate based on the aforementioned characteristics (i.e. distribution and habitat). Following an herbarium survey[1] a preliminary list was prepared. Field reconnaissance began in early summer and adjustments were made to the preliminary list because suitable populations could not be located for each species. Species were added because field observations indicated their appropriateness. The final list included: *Astragalus alpinus* L., *A. americanus* (Hook.) M.E. Jones, *A. vexilliflexus* Sheldon, *Hedysarum alpinum* L., *H. boreale* Nutt., *H. sulphurescens* Rydb., *Lupinus nootkatensis* Donn *ex* Sims, *L. sericeus* Pursh, *Oxytropis cusickii* Greenm., *O. deflexa* (Pall.) DC., *O. monticola* A. Gray, *O. sericea* Nutt., *O. splendens* Dougl. *ex* Hook., and *O. viscida* Nutt.

3.1 SEED COLLECTION

General collection locations were chosen prior to going into the field. These were chosen to include a range of latitudes and elevations within the Rocky Mountains and foothills (Figure 1). Collection dates were determined based on information obtained from the herbarium survey, and from preliminary forays to locations and sites in the mountains during flowering time. Final collection sites were selected based on accessibility and the presence of healthy, vigourous populations of the legume species.

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[1] Legume specimens from the University of Alberta, Department of Botany Herbarium (ALTA), the University of Alberta Devonian Botanic Garden Herbarium, and the herbarium at AEC were surveyed to determine habitats, elevations, distributions, and abundance for the mountains and foothills species.

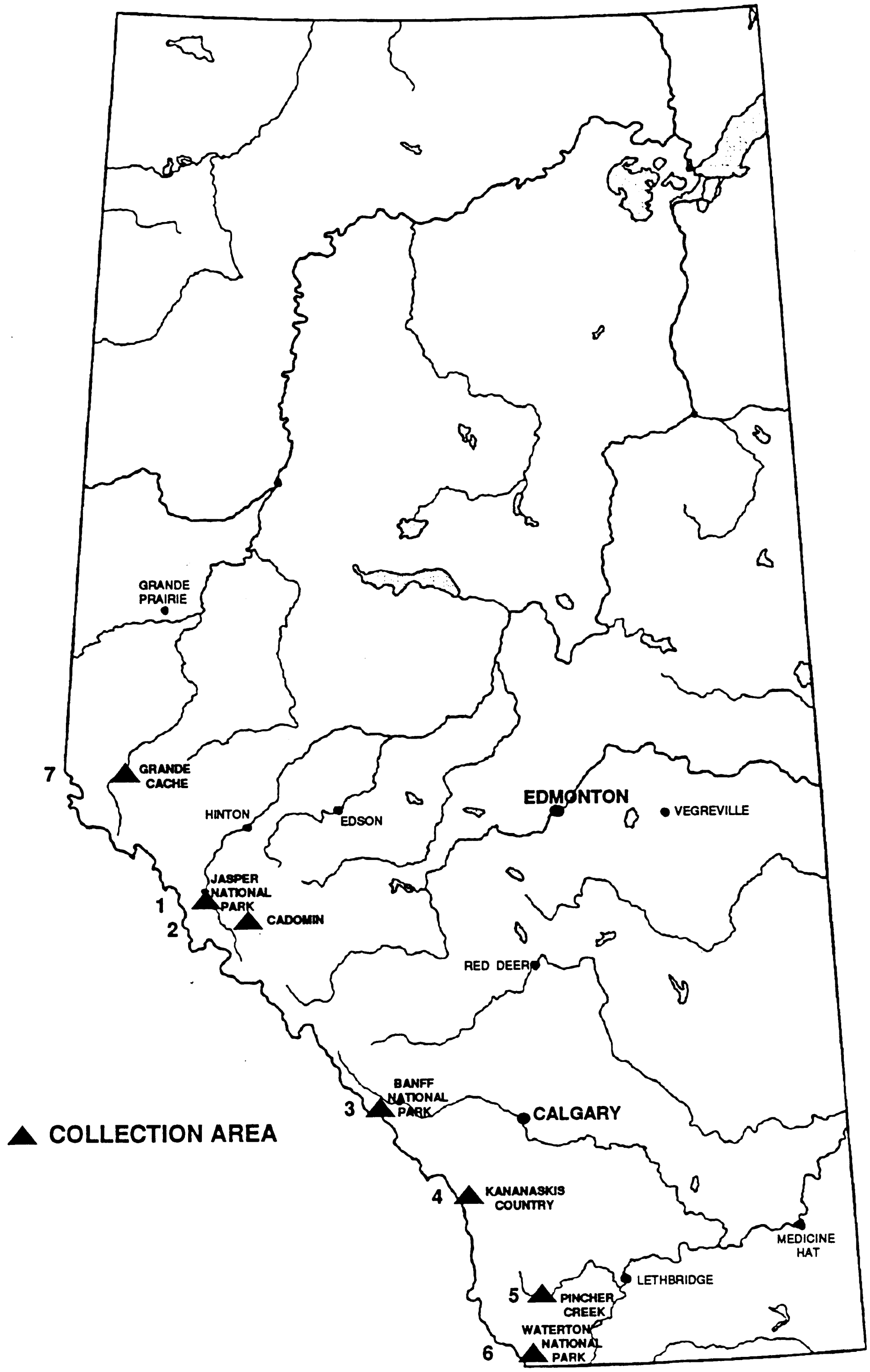

Figure 1 Location of legume collection areas in the mountains and foothills of Alberta.

In 1990, fifty-eight collections of legume seeds were made at 34 sites (Appendix 1) in six locations (Jasper, Cadomin, Banff, Kananaskis, Pincher Creek, and Waterton) (Table 1). Seed stalks were hand picked from selected plants at each site, placed in paper bags, given a field identification, labelled with species' name, site number, location, and date. Samples were transported to Alberta Environmental Centre (AEC), Vegreville, and air-dried at room temperature for six to eight weeks.

In June 1991, seven sites were selected in the Grande Cache area expanding legume collection to more northerly locations (Appendix 1). Seeds were collected from six legume species (*Astragalus americanus, Hedysarum alpinum, Lupinus nootkatensis, Oxytropis cusickii, O. deflexa,* and *O. splendens).* Further seed collections of *Hedysarum alpinum, Lupinus sericeus,* and *Oxytropis splendens* were made at previous sites.

Site descriptions were prepared for all collection sites and composite soil samples were taken and analyzed for nitrogen (N), phosphorus (P), sodium (NA), potassium (K), sulphur (S), soil reaction (pH), electrical conductivity (EC), organic matter (OM), free lime ($CaCo_3$) and hand texture. This information is available from the Alberta Environmental Centre.

3.2 SEED CLEANING

Seeds were cleaned using one of three methods (Table 2).

Method 1: Samples were threshed for 20 seconds in a soil grinder[2], or for one minute in a 25 cm diameter drum lined with corrugated rubber. Threshed seeds were then sieved[3] to remove large stems and chaff (sieve sizes 3.5, 5, 10, and 12). A size 40 sieve removed fine dust before final cleaning.

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[2] Dynacrush Model DC-1

[3] Canadian Standard Sieve Series, Combustion Engineering Canada Inc., St. Catharines, Ontario, Canada

Table 1 Location and dates of legume collections from the mountains and foothills of Alberta. Site numbers refer to specific sites at each location as described in Appendix 1.

Taxon	Collections			
	Location	Site	1990	1991
Astragalus alpinus	Cadomin	7	90-09-11	
(ASAL)	Banff	26	90-09-05	
	Kananaskis	28	90-09-09	
Astragalus americanus	Waterton	3	90-09-11	
(ASAM)	Cadomin	6	90-08-21	
	Jasper	11	90-08-22	
	Jasper	13	90-09-12	
	Banff	25	90-09-05	
	Kananaskis	28	90-09-19	
	Grande Cache	35,41		91-09-05
Astragalus vexilliflexus	Cadomin	6	90-08-21	
(ASVE)				
Hedysarum alpinum	Cadomin	4	90-08-20	91-08-15/91-09-05
(HEAL)	Cadomin	5	90-08-21	91-08-15/91-09-05
	Cadomin	6	90-08-21	
	Cadomin	9	90-09-11	91-09-05
	Jasper	10	90-08-21	91-08-15
	Jasper	11,17	90-09-13	91-09-04
	Jasper	16	90-09-12	91-09-04
	Banff	21	90-09-05	91-08-21/91-09-12
	Banff	22	90-09-05	
	Grande Cache	36		91-08-14
	Grande Cache	38		91-08-14/91-09-05
	Grande Cache	39		91-09-05
Hedysarum boreale	Cadomin	6	90-08-21	
(HEBO)	Cadomin	9	90-09-11	
	Jasper	10	90-09-11	
Hedysarum sulphurescens	Waterton	1	90-08-14	
(HESU)	Kananaskis	28,30	90-09-19	
Lupinus nootkatensis	Grande Cache	37		91-08-14
(LUNO)	Grande Cache	40		91-08-14
Lupinus sericeus	Waterton	1,2	90-08-14	91-08-08
(LUSE)	Waterton	3	90-08-14	91-08-07
	Pincher Creek	31	90-09-09	91-07-24
	Pincher Creek	32	90-07-20	91-07-24
	Pincher Creek	33	90-07-10	91-07-24
	Pincher Creek	42		91-07-25

Table 1 (concluded).

Taxon	Collections			
	Location	Site	1990	1991
Oxytropis cusickii	Cadomin	9	90-09-11	
(OXCU)	Grande Cache	38		91-08-14
	Grande Cache	41		91-09-05
Oxytropis deflexa	Cadomin	4	90-08-20	
(OXDE)	Jasper	15	90-09-12	
	Banff	23,24	90-09-05	
	Kananaskis	28	90-09-19	
	Grande Cache	41		91-09-05
Oxytropis monticola	Banff	19	90-09-04	
(OXMO)	Banff	20,22	90-09-05	
	Kananaskis	27,29	90-09-06	
	Kananaskis	28	90-09-19	
Oxytropis sericea	Pincher Creek	33	90-08-10	
(OXSE)	Pincher Creek	34	90-09-03	
Oxytropis splendens	Waterton	1		91-08-22
(OXSP)	Waterton	3	90-08-14	91-08-22
	Cadomin	4	90-08-20	91-09-05
	Cadomin	6	90-08-21	91-09-05
	Jasper	12	90-09-12	91-09-04/91-09-05
	Jasper	14	90-09-12	91-09-04
	Jasper	18	90-09-13	91-09-04
	Banff	19	90-09-04	91-09-05
	Banff	23	90-09-05	91-08-21/91-09-12
	Banff	24	90-09-05	91-08-21/91-09-24
	Grande Cache	35		91-09-05
	Grande Cache	38		91-09-05
	Grande Cache	39		91-09-05
Oxytropis viscida	Cadomin	6	90-08-21	
(OXVI)	Banff	24	90-09-05	

Method 2: Seed pods were hand-ground in a seed box[4]. For larger samples, an electric thresher was used to break pods from the stems. Sieves (sizes 5, 10, and 12) were used to remove the large stems and chaff. A size 18 sieve removed the fine dust prior to final cleaning.

Method 3: Samples were threshed for 30 seconds in an electric thresher to break pods from the stems. Pods were hand-ground in a seedbox with a pounder and a size 8 sieve was used to remove chaff. This procedure was repeated until all the seed pods had broken away from the stem.

Sieved seeds from all three methods were separated from the fine chaff using a seed blower[5]. The blower had an adjustable column of air which removed the heavier seeds from the fine chaff. Photographs of the seeds of each legume species were taken. These were kept on file for future reference and for field identification.

3.3 SEED WEIGHTS

Seed weights were calculated for each collection (each species at each site) by weighing 100 seeds. For multiple collections of the same species at various sites in a single location and from several locations, three samples of 100 seeds were weighed to determine if seeds weight varied by site or location.

3.4 GERMINATION

Beginning in January 1991, two germination experiments were undertaken. For both experiments, cicer milkvetch (*Astragalus cicer* 'Oxley') seed was used as a control. Prior to all germination testing, seeds were surface sterilized by soaking in a 2% sodium hypochlorite solution (NaOCL) for 10 minutes, and rinsing with distilled water. Seeds

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[4] A wooden box measuring 30 x 36 x 14 cm with a corrugated rubber bottom; a flat circular piece of plywood 24 cm with a handle in the centre is used to pound samples.

[5] Oregon Laboratories Seed Blower

Table 2 Seed cleaning methods used for Alberta legumes.

Legume Species	Seed Cleaning Methods*
Astragalus alpinus	2
Astragalus americanus	2
Astragalus vexilliflexus	2
Hedysarum alpinum	3
Hedysarum boreale	3
Hedysarum sulphurescens	3
Lupinus nootkatensis	1
Lupinus sericeus	1
Oxytropis deflexa	1
Oxytropis cusickii	1
Oxytropis monticola	1
Oxytropis sericea	1
Oxytropis splendens	1
Oxytropis viscida	1

* see description in text

were dried for several hours on blotter paper.

Scarification of *Astragalus*, *Hedysarum*, and *Oxytropis* was achieved by abrading seeds individually with 80 grit sandpaper. *Lupinus* seeds were held by hand and scratched with forceps or a razor blade. Each seed was inspected under a stereoscope to ensure that the seed coat was scratched and that the embryo was undamaged.

A randomized complete block experiment was set up to compare germination of each collection, and determine germination potential of each species. Four replicates of 25 sterilized seeds from each collection were scarified and placed into 15 mm petri dishes on two sheets of Whatman No. 1 filter paper and moistened with distilled water. Dishes were randomly placed on trays and housed in a germination chamber, at 22°C for 16 hours (light) and 15°C for 8 hours (dark). Distilled water was added as required.

Germination (considered complete when the radicle emerged from the testa) was counted daily for the first week and three times weekly for a period up to 28 days. Germinants were removed when counted. Mean germination was calculated for each species.

A second experiment (using a nested design) was undertaken to determine if there were differences in germination among seed lots of the same species collected at different sites within a location or from different locations. *Hedysarum alpinum, Lupinus sericeus,* and *Oxytropis splendens* were selected for this experiment since there were numerous collections of these species from various sites at several locations. The methods described previously were also used in this experiment. Seed weights were calculated for each collection of these species by averaging the weight of three replicates of 100 seeds each. Mean seed weights were correlated with mean germination and with germination index (GI = $\sum$(no. of seeds germinated x no. of days)/total no. of seeds germinated) (Acharya 1989).

3.5 EVALUATION NURSERY

Fifty seven populations representing 13 species of native legumes were seeded in March and April 1991 in Hillson 4 and 5 root trainers filled with a standard soil mix (one part each of loam, peat, sand and vermiculite). Seeds were scarified prior to seeding. All seeds were seeded directly into the root trainers, however when *Lupinus* seeds failed to germinate in root trainers, new seeds were germinated in the seed germinator (22/15°C) and the resulting seedlings were transferred to root trainers. Seedlings were produced at 22°C day/15°C night with 16 hour daylength and HID (High Intensity Discharge) lights in a greenhouse. Seedlings were given 20-20-20 fertilizer at 1/4 recommended strength when required as determined by assessment of leaf colour. Plants were hardened outdoors approximately 10 days prior to transplanting to the field at Vegreville.

Astragalus, Hedysarum, Lupinus species and *Oxytropis monticola* were transplanted into the plot in May. *Oxytropis deflexa, O. sericea,* and *O. splendens* were transplanted out in June. Extra seedlings of various collections were transplanted and grown for seed increase. Plants were watered immediately following transplanting. The field nursery at AEC consisted of two replicates. Plants were placed in rows of 25 plants per row with a spacing of 50 cm between plants and one metre between rows. Rows of each collection were randomized within blocks of each species, and blocks of species were randomized within each replicate. Plot layout is presented in Figure 2.

Transplants of *Lupinus nootkatensis* were not produced and placed in the field plot until the following year (1992). Therefore data collected on this species were not directly comparable with the other species but data were used to make final selections.

3.6 SPECIES EVALUATION

Survival of transplants was recorded in August as a percentage of those planted. Growth habit of each collection was noted as prostrate (flat), decumbent (trailing with the end tending to ascend), ascending (gradually turning upwards to a vertical position), or erect (upright). Vigour of each collection was rated from 1 (poor) to 5 (vigourous) based on the general look of the plants. An average plant height was calculated from the three most vigourous plants in each collection, and for plants that produced seed, height of the seed pods was measured.

In the first season, three flowering dates were recorded for each plot: first bloom, 50% of plants flowering in the plot, and 100% of plants flowering. Voucher specimens were prepared from collections which were flowering. Identification of each collection was confirmed using voucher specimens. To determine biomass, three predetermined (i.e. from the same position within each collection) plants of each collection were clipped 0.5 cm from the ground, placed in labelled paper bags, placed at 35°C until dry and weighed. Mature seed pods were hand clipped, from August to October, placed in labelled paper bags and dried at room temperature for 6 to 8 weeks. Seeds were cleaned using previously described methods. Seeds were weighed and yield recorded.

LEGUME COLLECTION REP 1				LEGUME COLLECTION REP 2			
NO.	TAXON	NO.	TAXON	NO.	TAXON	NO.	TAXON
101	OXVI-06	130	(mixed)	201	(mixed)	230	OXMO-27
102	OXSP-23	131	HEAL-11	202	HEAL-06	231	ASVE-06
103	OXSP-06	132	HEAL-09	203	HESU-28	232	LUNO-37
104	OXSP-19	133	HEAL-06	204	(mixed)	233	LUNO-37
105	OXSP-14	134	HEAL-17	205	HEAL-04	234	LUNO-40
106	OXSP-12	135	HEAL-22	206	HEAL-22	235	LUNO-40
107	OXSP-18	136	HEAL-16	207	HEAL-16	236	ASAM
108	OXSP-03	137	HEAL-05	208	HEAL-17	237	OXVI-06
109	OXSP-24	138	HESU-28	209	HEAL-09	238	LUSE-33
110	OXSP-04	139	HEAL-10	210	HEAL-05	239	LUSE-31
111	OXSE-34	140	(mixed)	211	HEAL-11	240	LUSE-32
112	OXSE-33	141	OXDE-28	212	HEAL-10	241	LUSE-03
113	OXMO-29	142	OXDE-23	213	HEBO-06	242	LUSE-02
114	OSCU-09	143	OXDE-15	214	HEBO-10	243	LUSE-01
115	OXMO-27	144	OXDE-24	215	HEBO-09	244	OXSP-06
116	OXMO-22	145	OXDE-04	216	OXSE-34	245	OXSP-04
117	OXVI-24	146	LUNO-37	217	OXSE-33	246	OXSP-19
118	OXMO-28	147	LUNO-37	218	HESU-30	247	OXSP-12
119	OXMO-19	148	ASAM	219	HESU-01	248	OXSP-18
120	OXMO-20	149	LUNO-40	220	OXDE-23	249	OXSP-14
121	HEBO-06	150	LUNO-40	221	OXDE-04	250	OXSP-24
122	HEBO-09	151	LUSE-32	222	OXDE-24	251	OXSP-23
123	HEBO-10	152	LUSE-31	223	OXDE-15	252	OXSP-03
124	HESU-30	153	LUSE-33	224	OXDE-28	253	OXMO-19
125	HESU-01	154	LUSE-01	225	ASAL-07	254	OXVI-24
126	ASAL-26	155	LUSE-02	226	ASAL-28	255	OXMO-22
127	ASAL-28	156	LUSE-03	227	ASAL-26	256	OXMO-20
128	ASAL-07	157	ASVE-06	228	OXMO-29	257	OXMO-28
129	HEAL-04			229	OXCU-09		

Figure 2 Nursery plot layout.

Germination tests were carried out as previously described on seeds harvested from the nursery plot.

Survival, vigour, diameter, and yield were recorded in the following two years as were plant height and seed pod height. In the first two seasons, seeds were harvested over the season as they ripened. In the third season, harvest for each collection began when it was judged that most seeds were ripe and all seed capsules were harvested at that time. If a second flush occurred these were also harvested and included in the total yield results. Observations were made on growth habit in each year and phenological data was also collected in the second and third season.

Survival, vigour, biomass, diameter, seed yield, and germination data were analyzed using GLM and Duncans Multiple Range Test (SAS Institute 1988). Collections for which the identification was questionable were not included in the analysis.

3.7 SEED INCREASE

In 1992, a seed trial/increase plot was seeded with six species to multiply the amount of seed that will be available for commercial production. Species chosen were those that had looked promising after 1991 results were analysed and for which sufficient seed was available.

The increase plot was prepared by cultivating and packing an area that had been fallow the previous year. Seeds were scarified prior to sowing. *Astragalus alpinus, Hedysarum alpinum*, and *Lupinus nootkatensis* were seeded at a rate of 1.68 kg/ha (1.5 lbs/ac) with 60 cm row spacings. *Oxytropis deflexa, O. monticola,* and *O. splendens* were seeded at a rate of 2.24 kg/ha (2 lbs/ac) with 40 cm row spacing. All species were shallow seeded (approximately 1 to 1.5 cm) using a Fabro seeder which also packs the soil following seeding. Seeds were collected from these plants as they ripened in both the first and second year.

3.8 PRELIMINARY RHIZOBIAL BACTERIA SCREENING

A preliminary screening of rhizobial bacteria strains was carried out with four Alberta legumes. Seeds of *Astragalus alpinus, Oxytropis monticola, O. deflexa*, and *Oxytropis splendens* were surface sterilized and scarified by soaking them for five minutes in concentrated sulphuric acid. Seeds were then rinsed in 10 rinses of sterile distilled water. Seeds were placed in petri dishes on Whatman #1 filter paper, and germinated at room temperature for one week. Eight seedlings of each species were transplanted into one of 15 Hillson-32 root trainers filled with sterilized vermiculite. These were watered regularly with a nutrient solution lacking nitrogen (one root trainer was watered with the nutrient solution with added nitrogen). Each of the root trainers were placed in an individual water tub. Each cell of the root trainer was inoculated with approximately 10^{-8} cells of a different rhizobial bacteria strain grown in Yeast Extract-Mannitol media (D. Prévost, Agriculture Canada, Ste.-Foy Québec, personal communication). These were monitored every four weeks for vigour and survival and were harvested at eight weeks. Wet and dry weights were measured and the extent of nodulation will be recorded. Data have yet to be analysed and only the most preliminary observations are reported here.

4. RESULTS AND EVALUATION

4.1 SEED WEIGHTS AND GERMINATION OF WILD COLLECTED SEEDS

Germination of all but one species (*Lupinus sericeus*) collected in the first year was greater than 90% (Table 3, see pages 46 to 55 for tables and figures for this section). All but three species had germination comparable to that of *Astragalus cicer* 'Oxley'. Only *Astragalus vexilliflexus, Oxytropis deflexa* and *Lupinus sericeus* had significantly less germination. The favourable germination results suggest that most species have potential for use in reclamation. Collection location had a significant effect on germination of *Lupinus sericeus* and *Oxytropis splendens* whereas location was not a factor in germination variability of *Hedysarum alpinum* (Table 4). This suggests that conditions under which plants are grown can affect germination; if a good growing environment is provided germination percentages and/or uniformity could be increased.

Average weights of seeds collected in the wild and those collected from the field nursery at Vegreville are presented in Table 5. The largest seeded species was *Lupinus sericeus* (approximately 1.5 to 2.8 g/100 seeds), and the smallest seeds were those of *Oxytropis deflexa* (many $\leq$ 0.1 g/100 seeds). Seed weights were found to affect germination of *Lupinus sericeus* and *Hedysarum alpinum* but not germination of *Oxytropis splendens* (Table 6). Final germination (after thirty days) was positively correlated with seed weight of *Lupinus sericeus*, whereas the germination index (a measure of germination rate) positively correlated with seed weight in the first week of germination for *Lupinus sericeus* and *Hedysarum alpinum.* These data suggest that although germination of *Lupinus sericeus* was low, that if other factors favour the use of this species in reclamation, selection for large seeded plants could improve germination.

4.2 DATA COLLECTED FROM NURSERY PLANTINGS

4.2.1 Survival

Survival of transplants over the first summer was high for most species; only four species had less than 70% transplant survival (*Hedysarum boreale, Oxytropis deflexa, Lupinus sericeus* and *Astragalus americanus*) (Figure 3). Data collected in the second growing season showed that only three species had a survival greater than 70% (*Astragalus alpinus, Oxytropis cusickii,* and *O. viscida*). Survival of *Astragalus americanus* after the first summer was only 49% and by May of the second year less than 1% of *Astragalus americanus* plants were living. This species was removed from further testing. There was further mortality among several species by the third year. Over the three growing seasons, *Astragalus alpinus* plants survived well with a recorded survival of 85%. *A. americanus, Hedysarum alpinum, Lupinus nootkatensis, L. sericeus, Oxytropis deflexa,* and *H. sulphurescens* had high mortality with less than 40% of plants surviving.

The high mortality rate observed for some species was attributed to the high populations of northern pocket gophers and Richardson's ground squirrels. These were particularly attracted to the *Hedysarum alpinum, H. sulphurescens,* and *Oxytropis monticola.* In each of these species the rodents would eat the taproot. Rodent damage was also noted on *Astragalus alpinus* but since it was a rhizomatous species the entire plant was not usually destroyed. Deer browse damage was also observed on *Oxytropis deflexa* and all three *Hedysarum* species. *Hedysarum alpinum* and *H. sulphurescens* often had what appeared to be a rust on the leaves. This might have been responsible for transplant mortality in the first season. Some insect damage was noted on some *Oxytropis deflexa* plants in the second season.

4.2.2 Growth and Development

Vigour varied from year to year within and among species. *Astragalus alpinus* was extremely vigourous in the first and second growing season however there was a noticeable reduction in vigour in the third year (Figure 4). Young transplants of *Lupinus nootkatensis* were also very vigourous however there was a considerable drop in vigour in the second year. *Hedysarum boreale*, on the other hand, demonstrated the opposite trend and vigour increased with age. Relatively good (and consistent) vigour was observed in all three years for *Astragalus vexilliflexus, Oxytropis monticola, O. cusickii, O. viscida, O. deflexa, O. sericea,* and *O. splendens. Astragalus americanus* plants were extremely weak in the first year. *Lupinus sericeus* transplants were weak and small in the first season, and many did not survive the winter (Figure 3). Those that survived into the second season had increased vigour in the second and third years (Figure 4). There was great variation in the vigour of *Hedysarum* species with many plants appearing extremely vigourous whereas other plants from the same collection were small and weak.

When vigour over the three growing seasons was averaged (Figure 5), *Astragalus alpinus* was the most vigourous, followed by *A. vexilliflexus, Oxytropis monticola, O. cusickii,* and *O. splendens, O. viscida,* and *O. sericea.* Of the species that survived more than one season, *Hedysarum alpinum, Lupinus sericeus,* and *Hedysarum sulphurescens* were the least vigourous.

In the first season *Astragalus alpinus* was found to produce a significantly greater amount of dry matter than all other species (Figure 6). The lowest values were recorded for *Oxytropis sericea, Astragalus americanus, O. cusickii, O. viscida* and *O. splendens.* The average yearly cover data over three years and overall cover are presented in Figures 7 and 8. Most species increased their cover in each of the three years, with *Hedysarum boreale* showing the greatest increase in the three years (Figure 7). *Astragalus alpinus, A. vexilliflexus,* and *Lupinus sericeus* however, all provided better cover in the second year and cover decreased in the third year. Although the best overall cover was provided by *Astragalus alpinus* (as would be expected by its rhizomatous nature) the increasing cover observed in other species suggests that these should be included in seed mixes to provide a persistent cover over time (Figure 8).

Growth habit of each species is described in Table 7. Species that consistently grow erect (*Astragalus americanus, Lupinus nootkatensis, Lupinus sericeus, Oxytropis cusickii* and *Hedysarum alpinum*) should be easier to harvest with conventional equipment whereas prostrate species (*Astragalus vexilliflexus*) cannot be harvested mechanically with equipment now available. Decumbent species may also present a problem for mechanical harvest. *Oxytropis monticola, O. sericea, O. splendens,* and *O. viscida* range from decumbent to erect. The seed pods of these species are generally erect but can lodge in heavy rain or hail.

The height of the seed pods is another factor that influences the ease with which these species can be mechanically harvested. *Astragalus vexilliflexus* and *A. alpinus* had the shortest stature, whereas *Lupinus nootkatensis* and *L. sericeus* were the tallest (Figure 9). All species except *Astragalus vexilliflexus* should be harvestable by mechanical means.

Because the nursery was set up in narrow rows, mechanical harvest by conventional methods was not possible however we did try out a hand held portable seed harvester (produced and patented by Prairie Habitats, Argyle, Manitoba). With some adaptation this harvest method could be used in trial field plots for most species.

4.2.3 Seed Yield

Most of the legumes did not produce seeds in their first year (Figure 10). Exceptions were *Oxytropis deflexa* (which produced significantly greater amounts of seed in the first year than any of the other species) and *Astragalus alpinus, Oxytropis monticola, Astragalus vexilliflexus*, *Hedysarum boreale*, and *Lupinus sericeus*. In the second year, all species produced seeds. The number of seeds produced in the second year was significantly greater for *Oxytropis deflexa* and *O. monticola* than for each of the other species, whereas *Hedysarum alpinum, Oxytropis cusickii,* and *Hedysarum sulphurescens* had poor seed yield with less than 100 seeds per plant.

Average seed production over three years is presented in Figure 11. *Oxytropis deflexa* and *O. monticola* were the most prodigious seed producers and *Oxytropis sericea, O. splendens* and *Astragalus alpinus* all produced relatively well. The poorest seed production was observed with *Lupinus sericeus, L. nootkatensis, Hedysarum sulphurescens, H. alpinum, Oxytropis cusickii* and *Hedysarum boreale*. Seed production by *Hedysarum* species was poor, possibly due to poor pollination. Seed pods often contained undeveloped seeds. The low yield recorded for *Astragalus vexilliflexus* was due to problems associated with harvesting this prostrate species. *Lupinus* seeds matured unevenly and were dispersed as they ripened; the best harvest date was difficult to ascertain. Most *Oxytropis* species maintained their seeds in the capsules unless rain or hail caused lodging.

4.2.4 Germination

Germination results from seed produced in the first year indicated that after 14 days seeds of *Oxytropis deflexa* and *Astragalus alpinus* had the highest germination percentages (99.5 and 98.3 respectively) (Table 8). *Hedysarum boreale* seed germination (71%) was significantly less than the previously discussed species whereas seeds of *Lupinus sericeus* germinated poorly (only 25%). Similar germination was observed in 1992 although after 14 days, no significant differences were observed among all species except *Lupinus sericeus* which had significantly less germination (Table 9). Up to day four of the germination tests, *Hedysarum boreale* germination was also significantly less than other species but was better than *Lupinus sericeus* germination.

4.2.5 Phenology

To efficiently cultivate and harvest seeds from Alberta legumes it is important to understand the annual cycle of development in these legumes. Table 10 presents phenological data for three years. These data will be discussed by species in the next section.

4.3 SEEDED INCREASE PLOTS

Astragalus alpinus was the only species for which a seed plot was successfully established. It emerged and grew well in the seeding year and some seed was produced. Of the remaining species, *Oxytropis monticola* and *O. splendens* had erratic emergence, but plants that did emerge grew well and produced small amounts of seeds particularly in the second year. Few seedlings of *Oxytropis deflexa* and *Lupinus nootkatensis* were produced and in the case of the former, these were not very vigourous. Little or no seed was produced by these plants in the first year. *Hedysarum alpinum* produced some seedlings, however these were not healthy nor vigourous.

4.4 PRELIMINARY RHIZOBIAL BACTERIA SCREENING

Preliminary observations of legumes inoculated with various *Rhizobia* indicated that there were differences in survival and growth of legumes inoculated with different bacterial strains. Growth of some legumes inoculated with certain *Rhizobia* was better than growth of the uninoculated controls. Different rhizobial strains affected different legumes.

The acid scarification methods used to scarify seeds for this screening process was found to be more or less effective on all legume species but some work needs to be done on the amount of time required for maximum germination.

Table 3 Germination of legumes collected in the Rocky Mountains and foothills in 1990 and the reclamation species *Astragalus cicer* 'Oxley'. Means followed by the same letter are not significantly different (P=0.05). * - species that were germinated under similar conditions but were not directly compared to 'Oxley'.

Taxon	Mean Germination (%)	
Astragalus cicer 'Oxley'	100	a
Oxytropis viscida	100	a
Hedysarum sulphurescens	100	a
Hedysarum boreale	100	a
Astragalus americanus	100	a
Astragalus alpinus	99	a
Oxytropis cusickii	99	ab
Oxytropis sericea	98	ab
Hedysarum alpinum	98	*
Oxytropis splendens	98	*
Oxytropis monticola	96	ab
Oxytropis deflexa	95	bc
Astragalus vexilliflexus	91	c
Lupinus sericeus	52	*

Table 4 Germination of three legume species collected from various locations. Within each species, locations with the same letter are not significantly different (P=0.05).

Collection Location	Germination (%)					
	Hedysarum alpinum		*Lupinus sericeus*		*Oxytropis splendens*	
Kananaskis	100	a				
Cadomin	99	a			100	a
Jasper	98	a			99	a
Banff	96	a			94	b
Waterton	95	a	54	a	100	a
Pincher Creek	--		51	b		

Table 5 Average weights of legume seeds collected in the wild in 1990 and 1991 and from the nursery in Vegreville in 1991 and 1992.

Taxon	Weight of 100 seeds (range/average) (g)			
	Native Collection 1990	Native Collection 1991	Vegreville Nursery 1991	Vegreville Nursery 1992
Astragalus alpinus	0.15 - 0.19 0.17		0.17 - 0.27 0.21	0.15 - 0.21 0.19
Astragalus americanus	0.36 - 0.46 0.41	0.51 - 0.53 0.52		0.53
Astragalus vexilliflexus	0.28		0.32	0.27 - 0.28 0.27
Hedysarum alpinum	0.37 - 0.51 0.43	0.33 - 0.60 0.45	0.35 - 0.36 0.35	0.36 - 0.55 0.42
Hedysarum boreale	0.45 - 0.58 0.50		0.52	0.21 - 0.70 0.50
Hedysarum sulphurescens	0.51 - 0.75 0.60			0.62 - 0.63 0.62
Lupinus nootkatensis		1.13 - 1.40 1.27		
Lupinus sericeus	1.51 - 2.84 2.16	1.49 - 2.65 2.17		2.24 - 2.78 2.51
Oxytropis monticola	0.12 - 0.14 0.13		0.14 - 0.18 0.17	0.12 - 0.18 0.14
Oxytropis cusickii	0.11 - 0.29 0.18	0.27 - 0.29 0.28		0.36
Oxytropis deflexa	0.07 - 0.10 0.08	0.05	0.08 - 0.11 0.09	0.08 - 0.10 0.09
Oxytropis sericea	0.18 - 0.19 0.18			0.21 - 0.25 0.23
Oxytropis splendens	0.11 - 0.16 0.14	0.03 - 0.16 0.12		0.11 - 0.77 0.14
Oxytropis viscida	0.16 - 0.18 0.17			0.10 - 0.20 0.18

Table 6 Correlation coefficients between germination and seed weights and germination index and seed weights in three legumes. * - Significant at P=0.05.

Day	Correlation Coefficient (r)	
	Seed wt. to germination	Seed wt. to germination index
Hedysarum alpinum		
3	0.26	0.64*
7	0.17	0.59*
14	0.22	0.53
21	0.21	0.52
28	0.21	0.52
Lupinus sericeus		
3	0.35	0.88*
7	0.21	0.60
14	0.62	0.27
21	0.82*	0.20
28	0.82*	0.21
Oxytropis splendens		
3	-0.01	-0.48
7	0.16	-0.23
14	0.10	-0.21
21	0.15	-0.19
28	0.15	-0.19

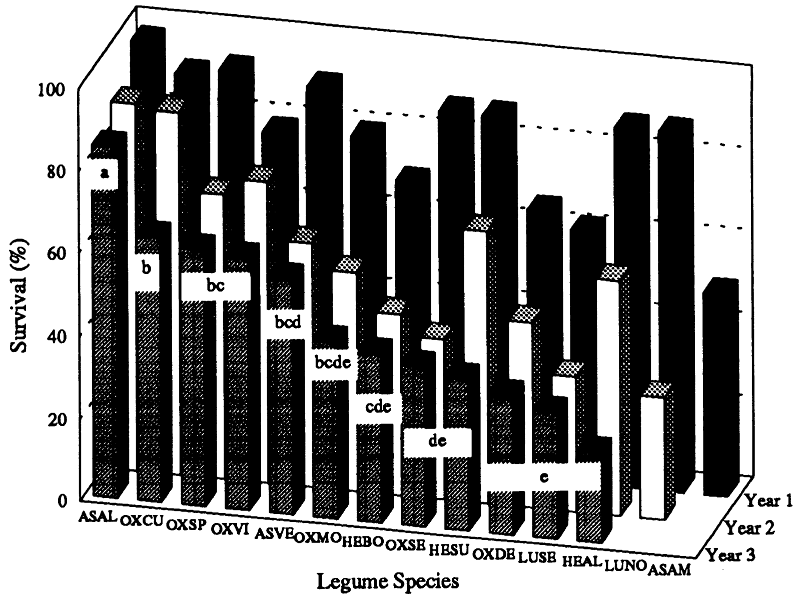

Figure 3 Survival of legume transplants in the nursery at Vegreville. Within the third year, bars labelled with the same letter are not significantly different (P≥0.01).

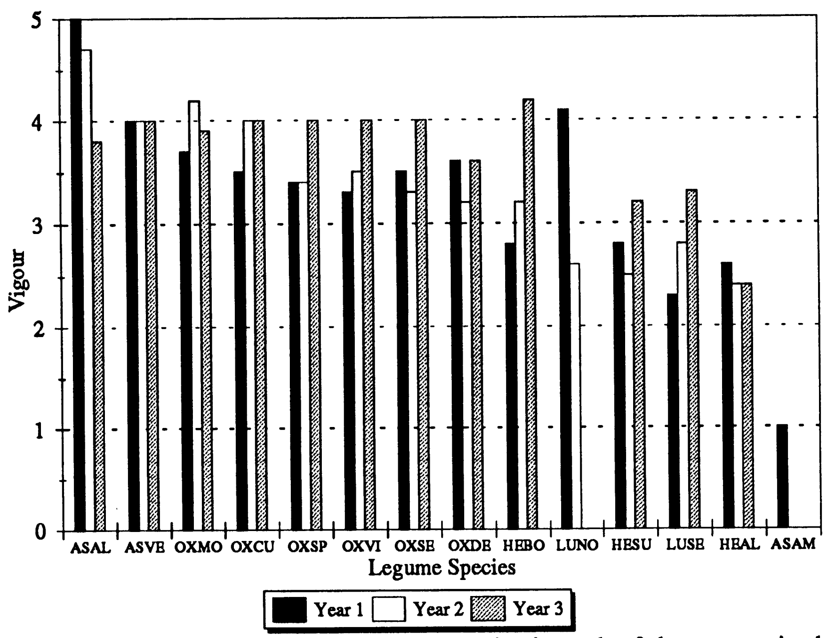

Figure 4 Vigour rating for each legume species in each of three years in the nursery at Vegreville.

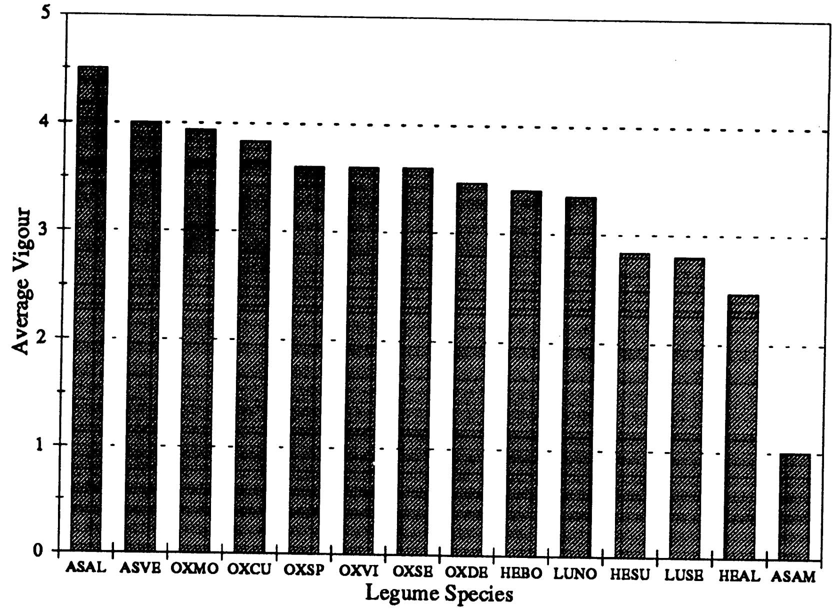

Figure 5 Average vigour of native legumes over three growing seasons in the nursery at Vegreville. (5=very vigourous; 1=poor vigour).

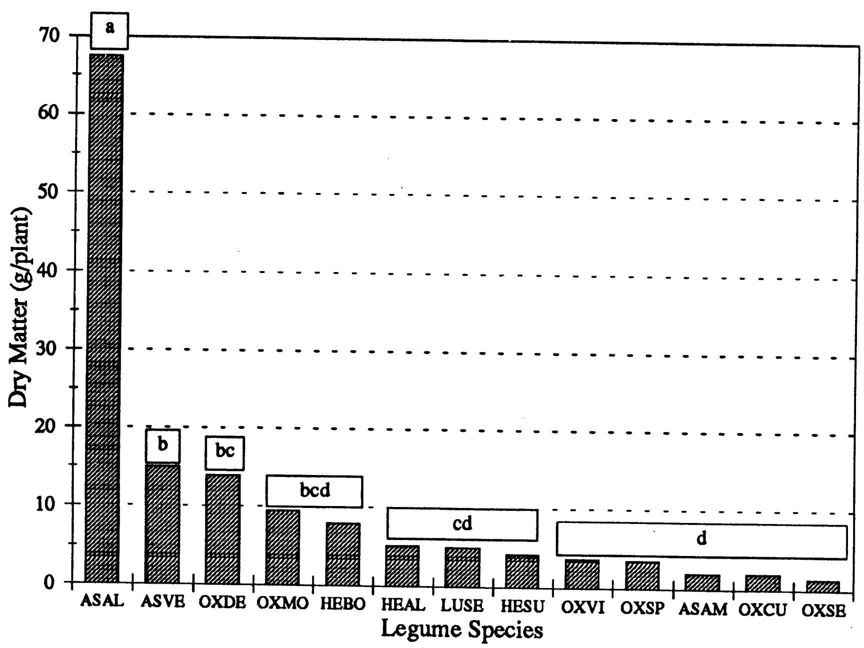

Figure 6 Average above-ground dry matter produced in the first season by legumes grown in the nursery at Vegreville. Bars labelled with the same letters are not significantly different (P≥0.01).

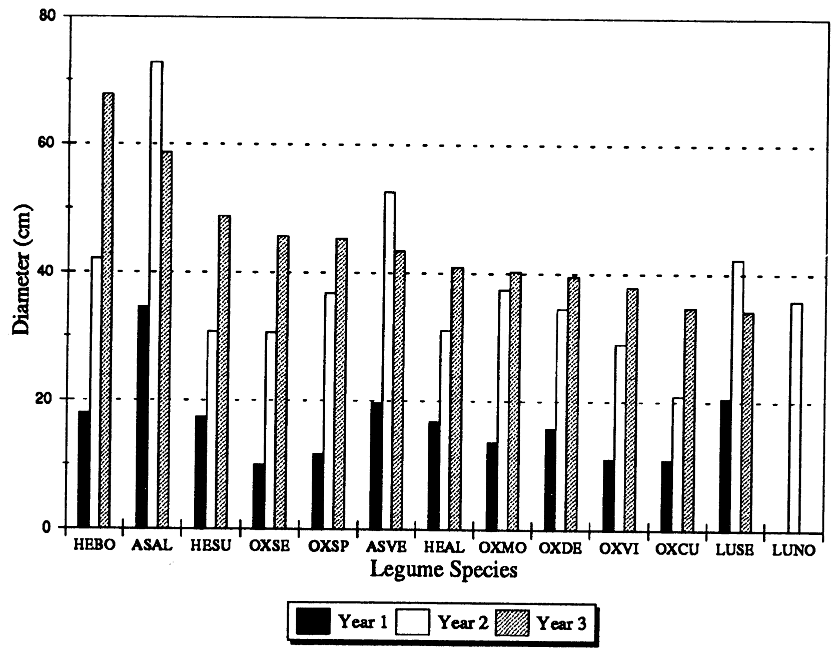

Figure 7 Average cover provided by each species growing in the field at Vegreville in each of three years.

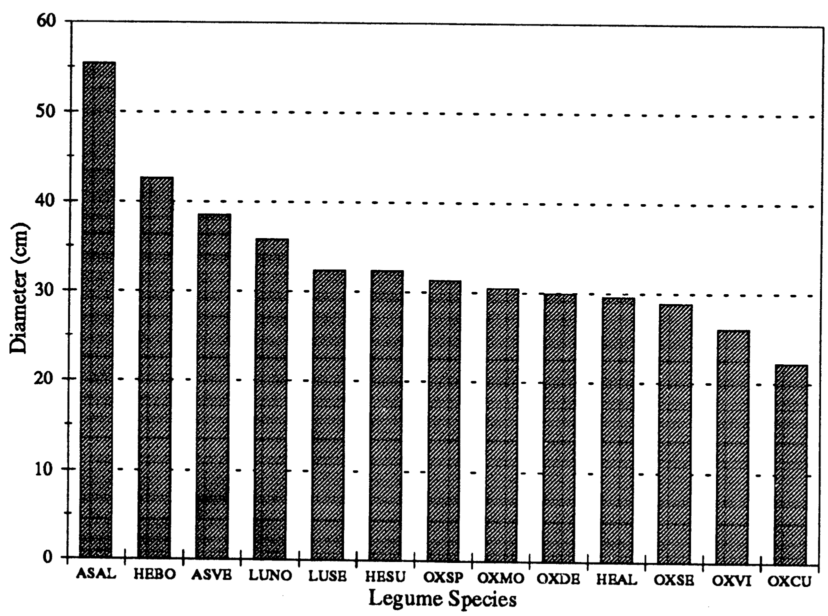

Figure 8 Average cover provided by legumes in the nursery at Vegreville over three years.

Table 7 Growth habit of legumes grown at Vegreville.

Taxon	Growth Habit
Astragalus alpinus	decumbent-ascending
Astragalus americanus	erect
Astragalus vexilliflexus	prostrate
Hedysarum alpinum	erect
Hedysarum boreale	ascending (decumbent-erect)
Hedysarum sulphurescens	erect (decumbent-erect)
Lupinus nootkatensis	erect
Lupinus sericeus	erect
Oxytropis cusickii	erect
Oxytropis deflexa	decumbent-ascending
Oxytropis monticola	ascending-erect
Oxytropis sericea	ascending-erect
Oxytropis splendens	decumbent-erect
Oxytropis viscida	ascending

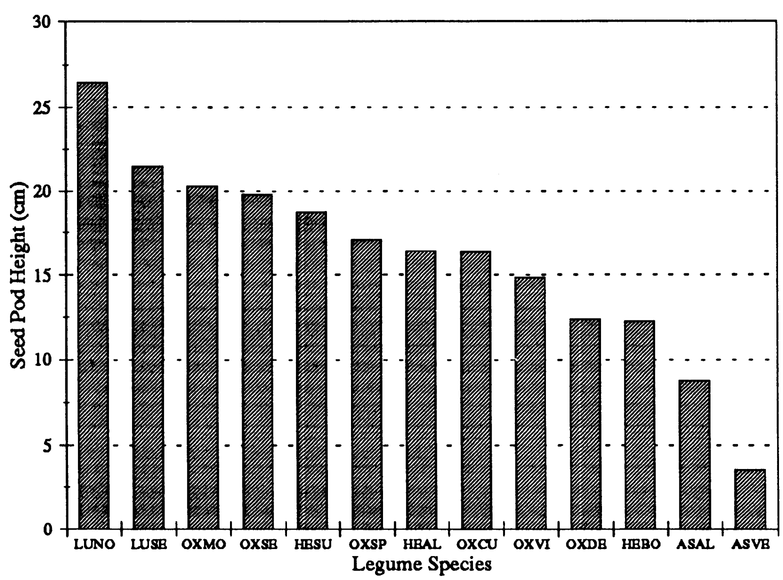

Figure 9 Average height of seed pods produced by Alberta legumes.

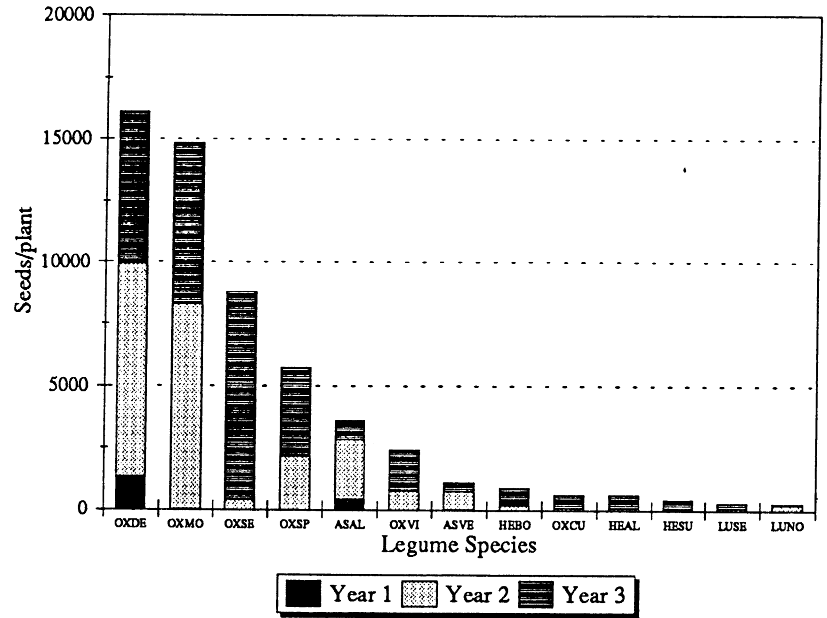

Figure 10 Cumulative seed production by legumes in the nursery at Vegreville over three years.

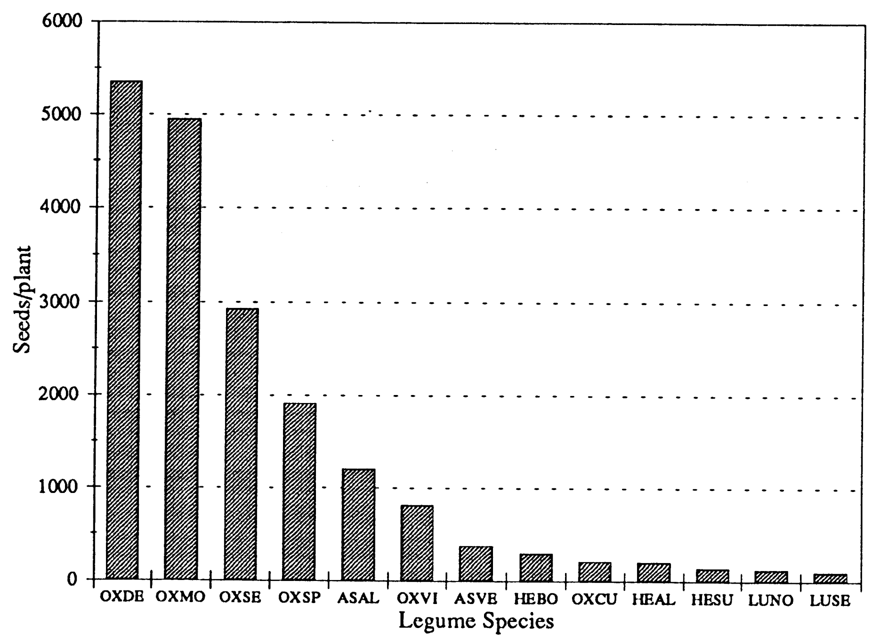

Figure 11 Average seeds produced per plant over three years in the nursery at Vegreville.

ERRATA SHEET

Figure 10, Page 53:

Legume species on the x-axis should be in the order presented below not as in original report.

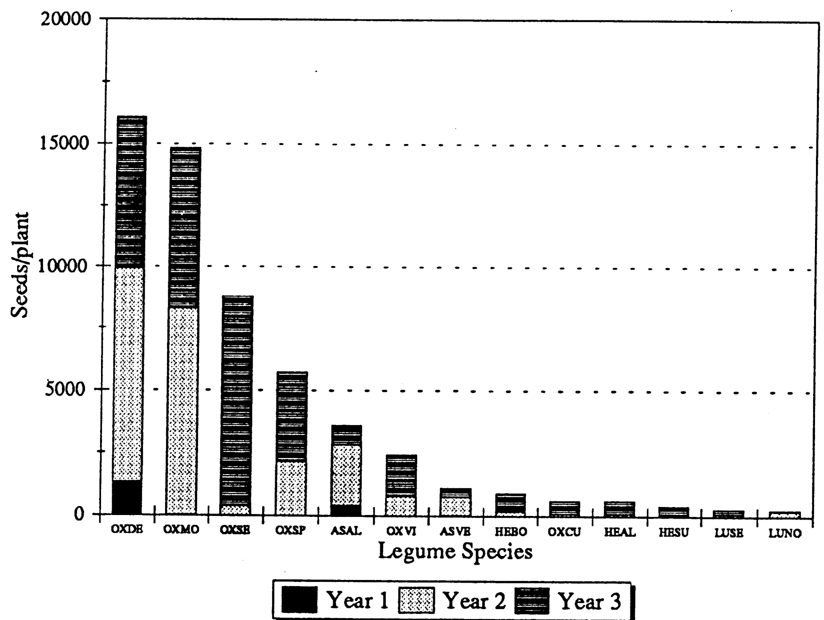

Figure 10 Cumulative seed production by legumes in the nursery at Vegreville over three years.

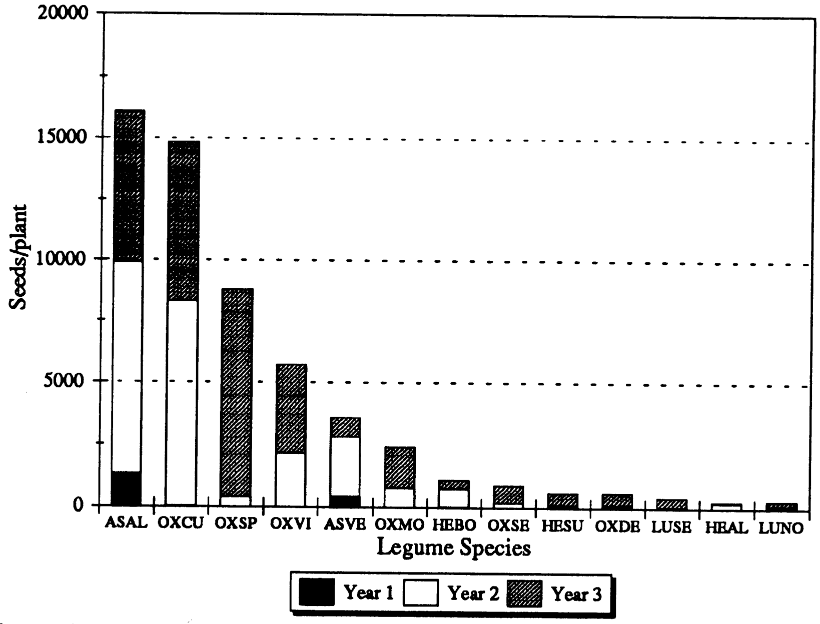

Figure 10 Cumulative seed production by legumes in the nursery at Vegreville over three years.

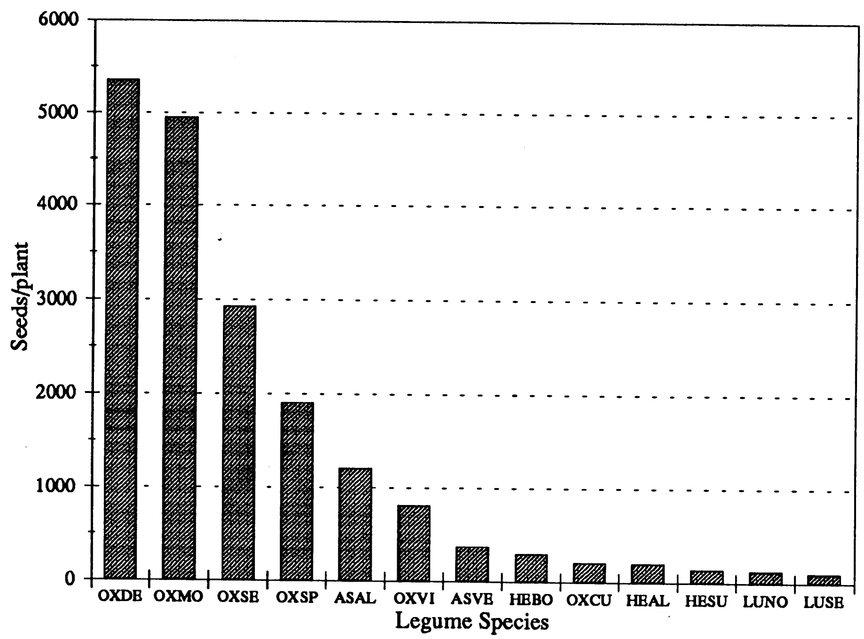

Figure 11 Average seeds produced per plant over three years in the nursery at Vegreville.

Table 8 Germination of legume seeds collected in the Vegreville nursery in 1991. Different letters within columns indicate significant differences (P=0.05).

Taxon	Day 4	Day 14	Total Germination Day 28
Oxytropis deflexa	A	A	99.5 A
Astragalus alpinus	B	A	98.3 B
Hedysarum boreale	B	B	70.8 B
Lupinus sericeus	C	C	24.8 C

Table 9 Germination of legume seeds collected from the Vegreville nursery in 1992. Different letters within a column indicate significant differences (P=0.05). * - not included in analysis due to a lack of replication.

Taxon	Germination (%)		
	Day 4	Day 14	Day 30
*Oxytropis cusickii**	100	100	100
Oxytropis sericea	100 a	100 a	100 a
Oxytropis monticola	100 a	100 a	100 a
Oxytropis splendens	100 a	100 a	100 a
Oxytropis viscida	100 a	100 a	100 a
Hedysarum sulphurescens	99 a	100 a	100 a
Astragalus alpinus	95 a	100 a	100 a
Hedysarum alpinum	95 a	98 a	98 a
Oxytropis delfexa	94 a	98 a	99 a
Hedysarum boreale	87 b	99 a	99 a
*Astragalus vexilliflexus**	56	96	100
Lupinus sericeus	25 c	54 b	83 b

Table 10 Phenology of Alberta legumes grown in the nursery at Vegreville.

Taxon		Dates for Developmental Stage		
		Buds	Flowers	Seeds
Astragalus alpinus	1992	May 4 - Aug 17	May 11 - Aug 31	Jul 6 - Sep 21
	1993	Apr 26 - Aug 30	May 17 - Sep 13	May 31 - Sep 27
Astragalus vexilliflexus	1992	May 4 - Aug 31	May 11 - Aug 31	Jul 6 - Sep 21
	1993	May 10 - Aug 23	May 17 - Sep 6	Jun 7 - Jul 5 Jul 26 - Sep 20
Hedysarum alpinum	1992	May 8 - Aug 10	May 25 - Aug 31	Jun 29 - Sep 27
	1993	May 3 - Aug 16	May 17 - Sep 13	Jun 7 - Sep 27
Hedysarum boreale	1992	May 11 - Aug 31	May 18 - Sep 21	Jun 29 - Sep 21
	1993	Apr 26 - Aug 23	May 10 - Sep 27	May 31 - Jul 12 Jul 26 - Sep 27
Hedysarum sulphurescens	1992	May 18 - Aug 10	May 25 - Aug 31	Jul 6 - Sep 28
	1993	May 3 - Jul 5 Aug 23 - Aug 30	May 17 - Jul 19 Aug 2 - Sept 13	Jun 7 - Jul 19 Aug 16 - Sep 13
Lupinus nootkatensis	1993	May 17 - Sep 16	May 24 - Sep 27	Jun 7 - Jul 5 Jul 19 - Sep 27
Lupinus sericeus	1992	Jun 15 - Sep 7 Sep 27	Jun 15 - Sep 7 Sep 27 - Oct 12	Jul 27 - Oct 5
	1993	May 17 - Sep 13	May 31 - Sep 27	Jun 14 - Sep 27
Oxytropis cusickii	1992	May 4 - May 25	May 11 - Jun 1	Jun 29 - Jul 6
	1993	Apr 26 - May 31	May 10 - Jun 7	May 31 - Jul 5
Oxytropis deflexa	1992	May 18 - Aug 10	Jun 1 - Aug 17	Jun 29 - Oct 5
	1993	May 10 - Jun 28 Jul 12 - Aug 30	May 31 - Jul 12 Jul 26 - Aug 30	Jun 7 - Jul 12 Aug 2 - Sep 27
Oxytropis monticola	1992	May 25 - Aug 31 Sep 21 - Oct 5	Jun 1 - Sep 7 Sep 27 - Oct 5	Jun 22 - Oct 5
	1993	Apr 26 - Jul 12 Aug 16 - Sep 13	May 17 - Aug 2 Aug 23 - Sep 27	Jun 14 - Aug 9 Sep 6 - Sep 27
Oxytropis sericea	1992	May 11 - Jun 8 Aug 17 - Aug 24	May 18 - Jun 15 Aug 17 - Sep 7	Jun 22 - Jul 5 Sep 21 - Oct 5
	1993	Apr 26 - Jun 7 Aug 2 - Aug 30	May 10 - Jul 12 Aug 9 - Sep 20	May 31 - Jul 12 Aug 23 - Sep 27
Oxytropis splendens	1992	Jun 1 - Aug 3 Aug 24 - Oct 5	Jun 8 - Aug 17 Aug 24 - Oct 5	Jun 22 - Sep 7 Sep 7 - Oct 5
	1993	Apr 26 - Aug 23	May 17 - Sept 27	Jun 21 - Sep 27
Oxytropis viscida	1992	May 18 - Aug 31	May 25 - Aug 31	Jul 6 - Oct 5
	1993	Apr 26 - Aug 30	May 17 - Sep 27	Jun 14 - Jul 12

5. SELECTION

Following the evaluation of measurable attributes of the 13 species in 1991, 1992, and 1993, species were ranked. The final ranking of the Alberta legumes is presented in Table 11. *Astragalus alpinus* proved to be the most promising species followed by *Oxytropis monticola* and *O. splendens*. *Astragalus vexilliflexus* was ranked fourth. *Astragalus americanus* was the species with the least potential, primarily because it did not survive well enough in the first season to be included in further testing. *Hedysarum alpinum, H. sulphurescens, Lupinus sericeus*, and *L. nootkatensis* were also ranked low. They did not survive well and produced few seeds. These species could have potential for use in certain areas but more work would be required before recommending these for use in reclamation.

Table 11 The rank order of Alberta legumes.

Species	Rank Order							
	Total Surv.	Ave Vigour	Ave Cover	Ave Seed Ht.	Ave Yield	Germ	Dist*	Final Rank
Astragalus alpinus	1	1	1	12	5	2	3	1
Oxytropis monticola	6	3	8	3	2	1	4	2
Oxytropis splendens	3	5	7	6	4	1	3	3
Astragalus vexilliflexus	5	2	3	13	7	1	5	4
Hedysarum boreale	7	9	2	11	8	4	2	5
Oxytropis sericea	8	7	11	4	3	1	6	5
Oxytropis cusickii	2	4	13	8	9	1	7	6
Oxytropis deflexa	10	8	9	10	1	3	4	7
Oxytropis viscida	4	6	12	9	6	1	7	7
Hedysarum sulphurescens	9	11	6	5	11	1	6	8
Lupinus nootkatensis	13	10	4	1	12	1	8	8
Lupinus sericeus	11	12	5	2	13	6	6	9
Hedysarum alpinum	12	13	10	7	10	5	1	10
Astragalus americanus	14	14	--	--	--	--	2	11

* distribution in Alberta

5.1 RECOMMENDED SPECIES

5.1.1 *Astragalus alpinus*

Astragalus alpinus has several attributes that make it a desirable species for use in reclamation and revegetation in Alberta. This legume:

1. is widely distributed in Alberta,
2. establishes rapidly and grows quickly,
3. is rhizomatous and spreads to form large mats that would be particularly effective for controlling erosion,
4. produces large amounts of seeds that germinate well, and
5. does not appear to be highly competitive.

Astragalus alpinus is a widespread species and is not only indigenous to the mountains and foothills but to some portions of northern Alberta (Moss 1983). This species is recommended for use at elevations of 1700 m to 2000 m in most areas of the mountains and foothills, and into northern regions of the province.

Producing seeds of *Astragalus alpinus* in a nursery was relatively simple. Following mechanical or chemical (H_2SO_4 for five to seven minutes) scarification it can be seeded at shallow depths in the spring at a rate of 1.68 kg/ha (1.5 lbs/ac) with 40 to 60 cm row spacing. Nursery survival was high and a good yield of viable seeds was produced in each of the first three years. Seed production was best in the second year, as vigour and survival were somewhat reduced in the third season, suggesting that its primary function in reclamation mixes would be a rapid cover species and should be used with longer lived more persistent native legumes.

The relatively low growing seed pods (approximately 5 cm) could present some problems when harvesting using conventional methods. Some success in mechanical harvest was attained using the hand-held seed harvester, although this method would not be feasible in harvesting large fields of this species. It also produced seeds over a long period of time (from mid-June to the end of September in 1992) and determining the best harvest date was difficult. Two harvest maybe feasible if regrowth is sufficient after the first harvest.

Astragalus alpinus grown in the field nursery were found to have rhizobia associated with the roots. Two rhizobial strains were isolated from these plants (by D. Prévost, Agriculture Canada, Ste.-Foy, Québec) and, along with several rhizobial strains isolated from this and other species in the arctic, are now being tested for their ability to improve establishment and growth of *Astragalus alpinus*.

Further work with this species is required in three areas:

1. testing at reclamation sites in areas of the mountains and foothills and in northern Alberta.
2. isolation and screening of rhizobial strains for use with this species in both nursery and reclamation conditions, and
3. continued nursery trials are required to refine seed production methodologies, particularly methods of harvesting.

Notwithstanding the requirement for further work, this species will be released for commercial production in the spring of 1994, and small quantities of seed could be available for retail as early as the fall of 1995.

5.1.2 *Oxytropis monticola*

Oxytropis monticola ranked second. There are several characteristics that make it an appropriate reclamation and revegetation species:

1. it is native to a wide range of areas of Alberta,
2. it grows in a wide variety of habitats including on disturbed sites, and
3. it produces large quantities of readily germinable seeds.

This ubiquitous species, found in the mountains, foothills, prairie, parkland, and in restricted areas of the boreal region of Alberta, is suitable for use on disturbed sites in many areas of the province. It is recommended for use at elevations up to 1800 m.

It is not a rhizomatous species and will not spread by vegetative means but seed production is high and should to some extent perpetuate itself by this means. It will not produce a dense cover and should allow establishment of other native plant species.

Although this species did not survive as well as some other legumes, it survived reasonably well in the nursery. Seeds were formed on stiff stalks well above the plants, and should prove to be easily harvested by mechanical means. Seeds, produced in late June to late September, were maintained in the upright pods unless lodging occurred. This species also has a second flowering period that could lead to a second harvest in some years. Seed production was extremely good. Seed germination was fast and uniform following mechanical scarification. Preliminary tests using acid scarification were not conclusive. A few seeds germinated in storage and seeds may require more drying prior to storage.

Small numbers of nodules were found on the roots of this legume growing in the nursery at Vegreville. Preliminary tests indicate that some strains will improve the growth of this species and a screening process of rhizobia should be carried out.

Further work with this species must be undertaken to:

1. Find effective seeding methods (i.e., depths, time of year, etc) for nursery production,
2. Isolate and develop effective *Rhizobia* strains for use in nurseries and at reclamation sites, and
3. Test its effectiveness for reclamation on disturbances in the mountains and foothills of Alberta.

5.1.3 *Oxytropis splendens*

Oxytropis splendens, widely distributed in the mountains and foothills and in northern Alberta, ranked third in the evaluation. Plants survived well in the nursery and produced prodigious amounts of seed. Seeds were produced in capsules on upright stalks and were generally maintained in the capsules until harvest unless plants were lodged by rain or hail. Seeds were produced from late June until late September. Following mechanical scarification, germination was excellent. Acid scarification was tried but more work needs to be done to refine the length of time required.

Some rhizobial nodulation was observed in the nursery and preliminary tests suggest that rhizobia may improve establishment and growth of this species. However, further work is required to isolate and test rhizobial strains.

Seeded plots of this species were not successful. Further investigation into seeding methods, timing, etc. will be required.

5.2 OTHER SPECIES

5.2.1 *Astragalus vexilliflexus*

Astragalus vexilliflexus ranked fourth. It is native to much of the mountains and foothills regions of Alberta, and is often found growing on disturbed sites. It was vigourous and survived reasonably well in the nursery. As with *Astragalus alpinus*, this species provided better cover in the second year than in the first or third years, and may be an early successional species that is not very persistent. It has good potential for erosion control due to its prostrate growth habit, however this prostrate habit was also responsible for poor seed harvests since seeds are produced under the branches on the ground. If a reasonable method of harvest could be found seed production could be improved. Further work will have to be undertaken before this species can be recommended for commercial production.

5.2.2 *Hedysarum boreale*

Although *Hedysarum boreale* plants were not very vigourous, had only average survival in the nursery, and had poor seed yield, it had several traits that make it desirable for reclamation and revegetation. It is native to most areas of the mountains and foothills, plains, and into the boreal regions and was collected to elevations of 2100 m. This legume produced large amounts of above-ground biomass and provided good cover compared to many of the other species. Both vigour and cover increased in each of the three years indicating that it is a longer living species than some. Seed yield was low however this also increased in each of the three years. Mortality was high over the first winter however survival in the following years was good.

If initial survival and vigour could be improved this species would provide some long term stability on reclaimed sites and provide good cover after the initial, fast growing, quick cover species started to die out. The benefits of rhizobial bacteria in establishment and growth would be worth investigating. The problem of poor seed yield, possibly due to the lack of pollination, also requires investigation.

No information is available regarding establishment of this species from seed in the nursery and seeding trials would provide valuable information prior to recommending its use in reclamation.

Seed germination was good within 14 days; a little slower than several other species. Mechanical scarification of seeds was difficult since seeds tended to crack. Acid scarification was not investigated.

5.2.3 *Oxytropis sericea*

Oxytropis sericea ranked fifth overall. Vigour and survival were average but it did not provide as much cover as many other of the species. Large numbers of seeds were produced on stiff stalks, 15 to 20 cm above the ground. Seeds were maintained within the capsules unless lodging occurred. Mechanically scarified seeds germinated very well.

This legume is native to the mountains and foothills but is primarily found at lower elevations (it was collected at sites up to 1150 m). It is also native to the plains and parklands, and may be of greater use for reclamation in these areas.

5.2.4 *Oxytropis cusickii*

Oxytropis cusickii was vigourous and survived well in the nursery at Vegreville. It was a small species and did not provide extensive cover. *Oxytropis cusickii* however, did produce a reasonable amount of seed that germinated well. Seeds were produced on shorter stalks than some other legumes, but at a height that should allow for mechanical harvesting. The seed capsules are located on stiff stalks and seeds are maintained in the capsules. This species produces seeds consistently during a short time, early in the season (late May through early July) and a harvest date is easily determined.

Although this legume is not widely distributed within Alberta, it is native to higher elevations than many other legumes (collected at 2100 m). This species is recommended for use at very high elevation sites only.

5.2.5 *Oxytropis deflexa*

Oxytropis deflexa ranked seventh among the legumes studied (as did *O. viscida*). The former species was not very vigourous and survival in the nursery was poor. It did not provide as much ground cover as many other species. Seed capsules were borne on decumbent to ascending stalks that may cause problems for mechanical harvesting. This species however produced the largest amount of seed in each of the three years. Seeds germinated well. This species is widely distributed in Alberta (mountains, foothills, parkland and boreal regions), and could be particularly useful in reclamation in many areas if the vigour and survival could be improved. Preliminary test results suggest that certain rhizobia strains will improve establishment and/or growth of this species.

5.2.6 *Oxytropis viscida*

Oxytropis viscida plants had average vigour and good survival in the nursery but did not provide much cover. This species had only average seed yield but seeds germinated well. Seeds were produced in capsules on stalks that reached to about 15 cm.

This legume has a restricted range in Alberta and is found primarily in mountains, foothills and adjacent plains in southwest Alberta. It was collected at lower elevations; up to about 1600 m.

5.2.7 *Hedysarum sulphurescens*

This species was collected primarily in the central and southern regions of the mountains and foothills but was found to elevations of 2100 m. However, its use in reclamation cannot be recommended at this time because *Hedysarum sulphurescens* plants had poor vigour and survival in the nursery at Vegreville. Survival decreased each of the three years. It did not provide as much cover as many of the other legumes. Seed yield was particularly poor but mechanically scarified seeds germinated well.

Further work will be required before this seed of this species can be produced efficiently in nurseries.

5.2.8 *Lupinus nootkatensis*

Although *Lupinus nootkatensis* is native to only a small area near Grande Cache, it has some potential for use in reclamation within that area and into British Columbia. This species was only tested for two years in the field nursery. Problems associated with this species included poor vigour and survival. It did however provide good ground cover, and seeds were produced in capsules, 25 to 30 cm above the ground. Seed yield was lower than most other species but seeds germinated well (100% in 1 to 4 days).

5.2.9 *Hedysarum alpinum*

The wide distribution range (not only in the mountains and foothills to elevation of 2100 m but throughout much of the province) suggests that this species would be particularly useful for reclamation in many parts of Alberta. However, *Hedysarum alpinum* was not vigourous and had very poor survival in the nursery at Vegreville. This species produced few seeds in any of the three years; probably due to a lack of pollination.

A small amount of seed was produced in the first season and germination of seeds produced in the initial season was lower than for most other species. Seeds produced in the second season however, germinated well. Since plants had an erect growth habit, seeds harvested using conventional methods should not be a problem.

Cover provided by this species increased in each of the three years (as with *Hedysarum boreale)*, and it may be useful in a mixtures as a long term component. Further study is required to improve establishment, survival, and seed production before it can be recommended for use on a large scale.

5.2.10 *Lupinus sericeus*

This species is native to the southern regions of Alberta, in the mountains and foothills (at elevations to 1550 m) and onto the adjacent plains. It was collected primarily at low elevation sites. Its use in reclamation projects will be restricted by its distribution but to a greater extent by its poor establishment, growth and yield in cultivation.

Lupinus sericeus was not very vigourous and survival was poor. It did not produce a great amount of cover, nor did it yield large amounts of seeds. Seeds of this and *L. nootkatensis* were difficult to collect or harvest because seeds capsules on a single stalk ripen over a period of time and as the capsule ripens seed are dispersed. *Lupinus* *sericeus* seeds did not germinate well. Seed germination could be improved if seed weights could be increased.

6. CONCLUSIONS

Astragalus alpinus has the best potential for use in reclamation in the mountains and foothills of Alberta up to elevations of 2000 m. It will be useful for establishing a rapid cover on sites but should be used in mixtures containing at least one longer lived, native legume since it appears to be somewhat short-lived. Immediate release of this species for commercial production is recommended so that large quantities of seeds will be available in the near future. When sufficient seed supplies are available this species should be tested extensively on reclamation sites. Continued screening of rhizobial strains will provide inoculum for use with this species in the nursery and at reclamation sites. Harvest methods for this species still require some testing.

Both *Oxytropis monticola* and *O. splendens* are also recommended for use in reclamation in the mountains and foothills in the near future. The former can be used up to 1800 m whereas the latter is recommended for up to 1600 m. Neither species will provide the abundant cover that *Astragalus alpinus* will provide but these species will be somewhat more persistent. Producing large quantities of good seed should be relatively easy if suitable seeding methods can be determined. The development of rhizobial strains for these species will further assist in the production of commercial quantities of seed and increase their effectiveness on disturbed sites. These species also require extensive testing in the mountains and foothills.

Other species with some potential for reclamation include:

1. *Astragalus vexilliflexus* if effective seed harvest techniques can be found,
2. *Hedysarum boreale,* particularly as a longer lived component of seed mixtures,
3. *Oxytropis sericea,* although this species may be best suited for lower elevations, and
4. *Oxytropis cusickii*, particularly at high elevation sites within its restricted native range.

More work is required for these before they can be released.

The remaining species require further study to overcome the problems encountered in establishing, growing, and harvesting seed in the nursery before commercial supplies of seed will become available.

To make the recommended species available as soon as possible we will be supplying seeds to a commercial nursery in the spring of 1994. If all goes well, seeds will be available in the fall of 1995.

There are two areas that need to be investigated before any of these species will be used extensively in reclamation projects. Each species that is being recommended must be tested at various sites in the mountains and foothills. This will provide users with more complete information regarding where and how to use each species in reclamation and restoration projects in Alberta.

Rhizobial bacteria, preferably isolated from sites in the mountains and foothills of Alberta, need to be tested and screened for use on native legumes. This is particularly important because results of preliminary screenings of rhizobial strains obtained from arctic regions of Canada (provided by Agriculture Canada, Ste.-Foy, Quebec) indicate that establishment and growth of at least four species can be improved with the introduction of the bacteria. Investigations with forage legumes have shown that rhizobial strains obtained from colder regions allow legumes to fix nitrogen at low temperatures, a desirable trait for reclaiming disturbances particularly in nutrient deficient soils.

There are several other areas of interest that should also be investigated regarding our native legumes. Information about invasiveness and persistence, competitive ability with weedy species, animal palatability, and relationships with other plants in seeding mixtures would assist in determining how and where these could or should be used.

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Appendix 1 Collection site locations and elevations.

Location	Site No.	Site Name	Elev. (m)
Jasper (1)	10	Overlander	1126
	11	Mt. Edith Cavell	1440
	12	Palisades picnic area	1050
	13	Medicine Lake picnic area	1470
	14	Lake Edith picnic area	1076
	15	Patricia Lake	1216
	16	Pyramid Lake	1216
	17	Meeting of the Waters picnic area	1170
	18	Wabasso Lake picnic area	1190
Cadomin (2)	4	Cadomin - 27 km s of Hinton	1360
	5	Cadomin townsite	1520
	6	Inland Cement	1586
	7	Mountain Park	1800
	8	North Prospect Creek	1800
	9	Cardinal River Divide	2100
Banff (3)	19	Two O'Clock Creek picnic area	1440
	20	Two Jack Lake, s side	1460
	21	Muleshoe picnic area	1430
	22	Sawbuck picnic area	1450
	23	Hillside Meadows pulloff	1460
	24	Johnston Canyon Resort	1470
	25	Corral Creek	1570
	26	Fairview picnic area	1700
Kananaskis (4)	27	Wilkinson Creek Hwy. 940	1826
	28	Valleyview picnic area Hwy. 40	2000
	29	Boulton Creek Trading Post	1790
	30	N. Wood/Pole cutting Hwy. 940	1866
Pincher Creek (5)	31	Oldman River (CR17)	1145
	32	Oldman River Dam (OS9)	1145
	33	Oldman River Dam (OS17)	1145
	34	Oldman River (CR25)	1145
	42	Oldman River Dam - RV park	1145
Waterton (6)	1	Cameron Lake Road (km 6)	1550
	1.1	Hay Barn Road	1310
	2	Slow Pinch Lookout	1300
	3	Blakiston Valley Lookout	1400
Grande Cache (7)	35	nr Willmore Wilderness entrance	1015
	36	Grande Cache townsite	1260
	37	Beaver Dam Road	1425
	38	Kissing Rock	1270
	39	Victor Lake	1140
	40	nr Smokey River Mine #8	1580
	41	Smokey River Mine #8	1580

RECLAMATION RESEARCH REPORTS

1. **RRTAC 79-2: Proceedings: Workshop on Native Shrubs in Reclamation. P.F. Ziemkiewicz, C.A. Dermott and H.P. Sims (Editors). 104 pp. No longer available.**

The Workshop was organized as the first step in developing a Native Shrub reclamation research program. The Workshop provided a forum for the exchange of information and experiences on three topics: propagation; outplanting; and, species selection.

2. **RRTAC 80-1: Test Plot Establishment: Native Grasses for Reclamation. R.S. Sadasivaiah and J. Weijer. 19 pp. No longer available.**

The report details the species used at three test plots in Alberta's Eastern Slopes. Site preparation, experimental design, and planting method are also described.

3. **RRTAC 80-2: Alberta's Reclamation Research Program - 1979. Reclamation Research Technical Advisory Committee. 22 pp. No longer available.**

This report describes the expenditure of $1,190,006 of Alberta Heritage Savings Trust Fund monies on research under the Land Reclamation Program. The report outlines the objectives and research strategies of the four program areas, and describes the projects funded under each program.

4. **RRTAC 80-3: The Role of Organic Compounds in Salinization of Plains Coal Mining Sites. N.S.C. Cameron et al. 46 pp. No longer available.**

This is a literature review of the chemistry of sodic mine spoil and the changes expected to occur in groundwater.

5. **RRTAC 80-4: Proceedings: Workshop on Reconstruction of Forest Soils in Reclamation. P.F. Ziemkiewicz, S.K. Takyi and H.F. Regier (Editors). 160 pp. $10.00**

Experts in the field of forestry and forest soils report on research relevant to forest soil reconstruction and discuss the most effective means of restoring forestry capability of mined lands.

6. **RRTAC 80-5: Manual of Plant Species Suitability for Reclamation in Alberta. L.E. Watson, R.W. Parker and D.F. Polster. 2 vols, 541 pp. No longer available; replaced by RRTAC 89-4.**

Forty-three grass, fourteen forb, and thirty-four shrub and tree species are assessed in terms of their suitability for use in reclamation. Range maps, growth habit, propagation, tolerance, and availability information are provided.

7. **RRTAC 81-1: The Alberta Government's Reclamation Research Program - 1980. Reclamation Research Technical Advisory Committee. 25 pp. No longer available.**

This report describes the expenditure of $1,455,680 of Alberta Heritage Savings Trust Fund monies on research under the Land Reclamation Program. The report outlines the objectives and research strategies of the four program areas, and describes the projects funded under each program.

8. **RRTAC 81-2: 1980 Survey of Reclamation Activities in Alberta. D.G. Walker and R.L. Rothwell. 76 pp. $10.00**

This survey is an update of a report prepared in 1976 on reclamation activities in Alberta, and includes research and operational reclamation, locations, personnel, etc.

9. **RRTAC 81-3: Proceedings: Workshop on Coal Ash and Reclamation. P.F. Ziemkiewicz, R. Stein, R. Leitch and G. Lutwick (Editors). 253 pp. $10.00**

Presents nine technical papers on the chemical, physical, and engineering properties of Alberta fly and bottom ashes, revegetation of ash disposal sites, and use of ash as a soil amendment. Workshop discussions and summaries are also included.

10. **RRTAC 82-1: Land Surface Reclamation: An International Bibliography. H.P. Sims and C.B. Powter. 2 vols, 292 pp. $10.00**

Literature to 1980 pertinent to reclamation in Alberta is listed in Vol. 1 and is also on the University of Alberta computing system (in a SPIRES database called RECLAIM). Vol. 2 comprises the keyword index and computer access manual.

11. **RRTAC 82-2: A Bibliography of Baseline Studies in Alberta: Soils, Geology, Hydrology and Groundwater. C.B. Powter and H.P. Sims. 97 pp. $5.00**

This bibliography provides baseline information for persons involved in reclamation research or in the preparation of environmental impact assessments. Materials, up to date as of December 1981, are available in the Alberta Environment Library.

12. **RRTAC 82-3: The Alberta Government's Reclamation Research Program - 1981. Reclamation Research Technical Advisory Committee. 22 pp. No longer available.**

This report describes the expenditure of $1,499,525 of Alberta Heritage Savings Trust Fund monies on research under the Land Reclamation Program. The report outlines the objectives and research strategies of the four program areas, and describes the projects funded under each program.

13. **RRTAC 83-1: Soil Reconstruction Design for Reclamation of Oil Sand Tailings. Monenco Consultants Ltd. 185 pp. No longer available**

Volumes of peat and clay required to amend oil sand tailings were estimated based on existing literature. Separate soil prescriptions were made for spruce, jack pine, and herbaceous cover types. The estimates form the basis of field trials (See RRTAC 92-4).

14. **RRTAC 83-2: The Alberta Government's Reclamation Research Program - 1982. Reclamation Research Technical Advisory Committee. 25 pp. No longer available.**

This report describes the expenditure of $1,536,142 of Alberta Heritage Savings Trust Fund monies on research under the Land Reclamation Program. The report outlines the objectives and research strategies of the four program areas, and describes the projects funded under each program.

15. **RRTAC 83-3: Evaluation of Pipeline Reclamation Practices on Agricultural Lands in Alberta. Hardy Associates (1978) Ltd. 205 pp. No longer available.**

Available information on pipeline reclamation practices was reviewed. A field survey was then conducted to determine the effects of pipe size, age, soil type, construction method, etc. on resulting crop production.

16. **RRTAC 83-4: Proceedings: Effects of Coal Mining on Eastern Slopes Hydrology. P.F. Ziemkiewicz (Editor). 123 pp. $10.00**

Technical papers are presented dealing with the impacts of mining on mountain watersheds, their flow characteristics, and resulting water quality. Mitigative measures and priorities were also discussed.

17. **RRTAC 83-5: Woody Plant Establishment and Management for Oil Sands Mine Reclamation. Techman Engineering Ltd. 124 pp. No longer available.**

This is a review and analysis of information on planting stock quality, rearing techniques, site preparation, planting, and procedures necessary to ensure survival of trees and shrubs in oil sand reclamation.

18. **RRTAC 84-1: Land Surface Reclamation: A Review of the International Literature. H.P. Sims, C.B. Powter and J.A. Campbell. 2 vols, 1549 pp. $20.00**

Nearly all topics of interest to reclamationists including mining methods, soil amendments, revegetation, propagation and toxic materials are reviewed in light of the international literature.

19. **RRTAC 84-2: Propagation Study: Use of Trees and Shrubs for Oil Sand Reclamation. Techman Engineering Ltd. 58 pp. $10.00**

This report evaluates and summarizes all available published and unpublished information on large-scale propagation methods for shrubs and trees to be used in oil sand reclamation.

20. **RRTAC 84-3: Reclamation Research Annual Report - 1983. P.F. Ziemkiewicz. 42 pp. $5.00**

This report describes the expenditure of $1,529,483 of Alberta Heritage Savings Trust Fund monies on research under the Land Reclamation Program. The report outlines the objectives and research strategies of the four program areas and describes the projects funded under each program.

21. **RRTAC 84-4: Soil Microbiology in Land Reclamation. D. Parkinson, R.M. Danielson, C. Griffiths, S. Visser and J.C. Zak. 2 vols, 676 pp. $10.00**

This is a collection of five reports dealing with re-establishment of fungal decomposers and mycorrhizal symbionts in various amended spoil types.

22. **RRTAC 85-1: Proceedings: Revegetation Methods for Alberta's Mountains and Foothills. P.F. Ziemkiewicz (Editor). 416 pp. $10.00.**

Results of long-term experiments and field experience on species selection, fertilization, reforestation, topsoiling, shrub propagation and establishment are presented.

23. **RRTAC 85-2: Reclamation Research Annual Report - 1984. P.F. Ziemkiewicz. 29 pp. No longer available.**

This report describes the expenditure of $1,320,516 of Alberta Heritage Savings Trust Fund monies on research under the Land Reclamation Program. The report outlines the objectives and research strategies of the four program areas and describes the projects funded under each program.

24. **RRTAC 86-1: A Critical Analysis of Settling Pond Design and Alternative Technologies. A. Somani. 372 pp. $10.00**

The report examines the critical issue of settling pond design, and sizing and alternative technologies. The study was co-funded with The Coal Association of Canada.

25. **RRTAC 86-2: Characterization and Variability of Soil Reconstructed after Surface Mining in Central Alberta. T.M. Macyk. 146 pp. No longer available.**

Reconstructed soils representing different materials handling and replacement techniques were characterized, and variability in chemical and physical properties was assessed. The data obtained indicate that reconstructed soil properties are determined largely by parent material characteristics and further tempered by materials handling procedures. Mining tends to create a relatively homogeneous soil landscape in contrast to the mixture of diverse soils found before mining.

26. **RRTAC 86-3: Generalized Procedures for Assessing Post-Mining Groundwater Supply Potential in the Plains of Alberta - Plains Hydrology and Reclamation Project. M.R. Trudell and S.R. Moran. 30 pp. $5.00**

In the Plains region of Alberta, the surface mining of coal generally occurs in rural, agricultural areas in which domestic water supply requirements are met almost entirely by groundwater. Consequently, an important aspect of the capability of reclaimed lands to satisfy the needs of a residential component is the post-mining availability of groundwater. This report proposes a sequence of steps or procedures to identify and characterize potential post-mining aquifers.

27. **RRTAC 86-4: Geology of the Battle River Site: Plains Hydrology and Reclamation Project. A. Maslowski-Schutze, R. Li, M. Fenton and S.R. Moran. 86 pp. $10.00**

This report summarizes the geological setting of the Battle River study site. It is designed to provide a general understanding of geological conditions adequate to establish a framework for hydrogeological and general reclamation studies. The report is not intended to be a detailed synthesis such as would be required for mine planning purposes.

28. **RRTAC 86-5: Chemical and Mineralogical Properties of Overburden: Plains Hydrology and Reclamation Project. A. Maslowski-Schutze. 71 pp. $10.00**

This report describes the physical and mineralogical properties of overburden materials in an effort to identify individual beds within the bedrock overburden that might be significantly different in terms of reclamation potential.

29. **RRTAC 86-6: Post-Mining Groundwater Supply at the Battle River Site: Plains Hydrology and Reclamation Project. M.R. Trudell, G.J. Sterenberg and S.R. Moran. 49 pp. $5.00**

The report deals with the availability of water supply in or beneath cast overburden to support post-mining land use, including both quantity and quality considerations. The study area is in the Battle River Mining area in east-central Alberta.

30. **RRTAC 86-7: Post-Mining Groundwater Supply at the Highvale Site: Plains Hydrology and Reclamation Project. M.R. Trudell. 25 pp. $5.00**

This report evaluates the availability of water supply in or beneath cast overburden to support post-mining land use, including both quantity and quality considerations. The study area is the Highvale mining area in west-central Alberta.

31. **RRTAC 86-8: Reclamation Research Annual Report - 1985. P.F. Ziemkiewicz. 54 pp. $5.00**

This report describes the expenditure of $1,168,436 of Alberta Heritage Savings Trust Fund monies on research under the Land Reclamation Program. The report outlines the objectives and research strategies of the four program areas and describes the projects funded under each program.

32. **RRTAC 86-9: Wildlife Habitat Requirements and Reclamation Techniques for the Mountains and Foothills of Alberta. J.E. Green, R.E. Salter and D.G. Walker. 285 pp. No longer available.**

This report presents a review of relevant North American literature on wildlife habitats in mountain and foothills biomes, reclamation techniques, potential problems in wildlife habitat reclamation, and potential habitat assessment methodologies. Four biomes (Alpine, Subalpine, Montane, and Boreal Uplands) and 10 key wildlife species (snowshoe hare, beaver, muskrat, elk, moose, caribou, mountain goat, bighorn sheep, spruce grouse, and white-tailed ptarmigan) are discussed. The study was co-funded with The Coal Association of Canada.

33. **RRTAC 87-1: Disposal of Drilling Wastes. L.A. Leskiw, E. Reinl-Dwyer, T.L. Dabrowski, B.J. Rutherford and H. Hamilton. 210 pp. No longer available.**

Current drilling waste disposal practices are reviewed and criteria in Alberta guidelines are assessed. The report also identifies research needs and indicates mitigation measures. A manual provides a decision-making flowchart to assist in selecting methods of environmentally safe waste disposal.

34. **RRTAC 87-2: Minesoil and Landscape Reclamation of the Coal Mines in Alberta's Mountains and Foothills. A.W. Fedkenheuer, L.J. Knapik and D.G. Walker. 174 pp. No longer available.**

This report reviews current reclamation practices with regard to site and soil reconstruction and re-establishment of biological productivity. It also identifies research needs in the Mountain-Foothills area. The study was co-funded with The Coal Association of Canada.

35. **RRTAC 87-3: Gel and Saline Drilling Wastes in Alberta: Workshop Proceedings. D.A. Lloyd (Compiler). 218 pp. No longer available.**

Technical papers were presented which describe: mud systems used and their purpose; industrial constraints; government regulations, procedures and concerns; environmental considerations in waste disposal; and toxic constituents of drilling wastes. Answers to a questionnaire distributed to participants are included in an appendix.

36. **RRTAC 87-4: Reclamation Research Annual Report - 1986. 50 pp. No longer available.**

This report describes the expenditure of $1,186,000 of Alberta Heritage Savings Trust Fund monies on research under the Land Reclamation Program. The report outlines the objectives and research strategies of the four program areas and describes the projects funded under each program.

37. **RRTAC 87-5: Review of the Scientific Basis of Water Quality Criteria for the East Slope Foothills of Alberta. Beak Associates Consulting Ltd. 46 pp. $10.00**

The report reviews existing Alberta guidelines to assess the quality of water drained from coal mine sites in the East Slope Foothills of Alberta. World literature was reviewed within the context of the East Slopes environment and current mining operations. The ability of coal mine operators to meet the various guidelines is discussed. The study was co-funded with The Coal Association of Canada.

38. **RRTAC 87-6: Assessing Design Flows and Sediment Discharge on the Eastern Slopes. Hydrocon Engineering (Continental) Ltd. and Monenco Consultants Ltd. 97 pp. $10.00**

The report provides an evaluation of current methodologies used to determine sediment yields due to rainfall events in well-defined areas. Models are available in Alberta to evaluate water and sediment discharge in a post-mining situation. SEDIMOT II (Sedimentology Disturbed Modelling Techniques) is a single storm model that was developed specifically for the design of sediment control structures in watersheds disturbed by surface mining and is well suited to Alberta conditions. The study was co-funded with The Coal Association of Canada.

39. **RRTAC 87-7: The Use of Bottom Ash as an Amendment to Sodic Spoil. S. Fullerton. 83 pp. No longer available.**

The report details the use of bottom ash as an amendment to sodic coal mine spoil. Several rates and methods of application of bottom ash to sodic spoil were tested to determine which was the best at reducing the effects of excess sodium and promoting crop growth. Field trials were set up near the Vesta mine in East Central Alberta using ash readily available from a nearby coal-fired thermal generating station. The research indicated that bottom ash incorporated to a depth of 30 cm using a subsoiler provided the best results.

40. **RRTAC 87-8: Waste Dump Design for Erosion Control. R.G. Chopiuk and S.E. Thornton. 45 pp. $5.00**

This report describes a study to evaluate the potential influence of erosion from reclaimed waste dumps on downslope environments such as streams and rivers. Sites were selected from coal mines in Alberta's mountains and foothills, and included resloped dumps of different configurations and ages, and having different vegetation covers. The study concluded that the average annual amount of surface erosion is minimal. As expected, erosion was greatest on slopes which were newly regraded. Slopes with dense grass cover showed no signs of erosion. Generally, the amount of erosion decreased with time, as a result of initial loss of fine particles, the formation of a weathered surface, and increased vegetative cover.

41. **RRTAC 87-9: Hydrogeology and Groundwater Chemistry of the Battle River Mining Area. M.R. Trudell, R.L. Faught and S.R. Moran. 97 pp. No longer available.**

This report describes the premining geologic conditions in the Battle River coal mining area including the geology as well as the groundwater flow patterns, and the groundwater quality of a sequence of several water-bearing formations extending from the surface to a depth of about 100 metres.

42. **RRTAC 87-10: Soil Survey of the Plains Hydrology and Reclamation Project - Battle River Project Area. T.M. Macyk and A.H. MacLean. 62 pp. plus 8 maps. $10.00**

The report evaluates the capability of post-mining landscapes and assesses the changes in capability as a result of mining, in the Battle River mining area. Detailed soils information is provided in the report for lands adjacent to areas already mined as well as for lands that are destined to be mined. Characterization of the reconstructed soils in the reclaimed areas is also provided. Data were collected from 1979 to 1985. Eight maps supplement the report.

43. **RRTAC 87-11: Geology of the Highvale Study Site: Plains Hydrology and Reclamation Project. A. Maslowski-Schutze. 78 pp. $10.00**

The report is one of a series that describes the geology, soils and groundwater conditions at the Highvale Coal Mine study site. The purpose of the study was to establish a summary of site geology to a level of detail necessary to provide a framework for studies of hydrogeology and reclamation.

44. **RRTAC 87-12: Premining Groundwater Conditions at the Highvale Site. M.R. Trudell and R. Faught. 83 pp. No longer available.**

This report presents a detailed discussion of the premining flow patterns, hydraulic properties, and isotopic and hydrochemical characteristics of five layers within the Paskapoo Geological Formation, the underlying sandstone beds of the Upper Horseshoe Canyon Formation, and the surficial glacial drift.

45. **RRTAC 87-13: An Agricultural Capability Rating System for Reconstructed Soils. T.M. Macyk. 27 pp. $5.00**

This report provides the rationale and a system for assessing the agricultural capability of reconstructed soils. Data on the properties of the soils used in this report are provided in RRTAC 86-2.

46. **RRTAC 88-1: A Proposed Evaluation System for Wildlife Habitat Reclamation in the Mountains and Foothills Biomes of Alberta: Proposed Methodology and Assessment Handbook. T.R. Eccles, R.E. Salter and J.E. Green. 101 pp. plus appendix. $10.00**

The report focuses on the development of guidelines and procedures for the assessment of reclaimed wildlife habitat in the Mountains and Foothills regions of Alberta. The technical section provides background documentation including a discussion of reclamation planning, a listing of reclamation habitats and associated key wildlife species, conditions required for development, recommended revegetation species, suitable reclamation techniques, a description of the recommended assessment techniques and a glossary of basic terminology. The assessment handbook section contains basic information necessary for evaluating wildlife habitat reclamation, including assessment scoresheets for 15 different reclamation habitats, standard methodologies for measuring habitat variables used as assessment criteria, and minimum requirements for certification. This handbook is intended as a field manual that could potentially be used by site operators and reclamation officers. The study was co-funded with The Coal Association of Canada.

47. **RRTAC 88-2: Plains Hydrology and Reclamation Project: Spoil Groundwater Chemistry and its Impacts on Surface Water. M.R. Trudell (Compiler). 135 pp. No longer available.**

Two reports comprise this volume. The first "Chemistry of Groundwater in Mine Spoil, Central Alberta," describes the chemical make-up of spoil groundwater at four mines in the Plains of Alberta. It explains the nature and magnitude of changes in groundwater chemistry following mining and reclamation. The second report, "Impacts of Surface Mining on Chemical Quality of Streams in the Battle River Mining Area," describes the chemical quality of water in streams in the Battle River mining area, and the potential impact of groundwater discharge from surface mines on these streams.

48. **RRTAC 88-3: Revegetation of Oil Sands Tailings: Growth Improvement of Silver-berry and Buffalo-berry by Inoculation with Mycorrhizal Fungi and N_2-Fixing Bacteria. S. Visser and R.M. Danielson. 98 pp. $10.00**

The report provides results of a study: (1) To determine the mycorrhizal affinities of various actinorrhizal shrubs in the Fort McMurray, Alberta region; (2) To establish a basis for justifying symbiont inoculation of buffalo-berry and silver-berry; (3) To develop a growing regime for the greenhouse production of mycorrhizal, nodulated silver-berry and buffalo-berry; and, (4) To conduct a field trial on reconstructed soil on the Syncrude Canada Limited oil sands site to critically evaluate the growth performance of inoculated silver-berry and buffalo-berry as compared with their un-inoculated counterparts.

49. **RRTAC 88-4: Plains Hydrology and Reclamation Project: Investigation of the Settlement Behaviour of Mine Backfill. D.R. Pauls (compiler). 135 pp. $10.00**

This three part volume covers the laboratory assessment of the potential for subsidence in reclaimed landscapes. The first report in this volume, "Simulation of Mine Spoil Subsidence by Consolidation Tests," covers laboratory simulations of the subsidence process particularly as it is influenced by resaturation of mine spoil. The second report, "Water Sensitivity of Smectitic Overburden: Plains Region of Alberta," describes a series of laboratory tests to determine the behaviour of overburden materials when brought into contact with water. The report entitled "Classification System for Transitional Materials: Plains Region of Alberta," describes a lithological classification system developed to address the characteristics of the smectite rich, clayey transition materials that make up the overburden in the Plains of Alberta.

50. **RRTAC 88-5: Ectomycorrhizae of Jack Pine and Green Alder: Assessment of the Need for Inoculation, Development of Inoculation Techniques and Outplanting Trials on Oil Sand Tailings. R.M. Danielson and S. Visser. 177 pp. No longer available.**

The overall objective of this research was to characterize the mycorrhizal status of Jack Pine and Green Alder which are prime candidates as reclamation species for oil sand tailings and to determine the potential benefits of mycorrhizae on plant performance. This entailed determining the symbiont status of container-grown nursery stock and the quantity and quality of inoculum in reconstructed soils, developing inoculation techniques and finally, performance testing in an actual reclamation setting.

51. **RRTAC 88-6: Reclamation Research Annual Report - 1987. Reclamation Research Technical Advisory Committee. 67 pp. No longer available.**

This annual report describes the expenditure of $500,000.00 of Alberta Heritage Savings Trust Fund monies on research under the Land Reclamation Program. The report outlines the objectives and research strategies of the four program areas, and describes the projects funded under each program.

52. **RRTAC 88-7: Baseline Growth Performance Levels and Assessment Procedure for Commercial Tree Species in Alberta's Mountains and Foothills. W.R. Dempster and Associates Ltd. 66 pp. $5.00**

Data on juvenile height development of lodgepole pine and white spruce from cut-over or burned sites in the Eastern Slopes of Alberta were used to define reasonable expectations of early growth performance as a basis for evaluating the success of reforestation following coal mining. Equations were developed predicting total seedling height and current annual height increment as a function of age and elevation. Procedures are described for applying the equations, with further adjustments for drainage class and aspect, to develop local growth performance against these expectations. The study was co-funded with The Coal Association of Canada.

53. **RRTAC 88-8: Alberta Forest Service Watershed Management Field and Laboratory Methods. A.M.K. Nip and R.A. Hursey. 4 Sections, various pagings. $10.00**

Disturbances such as coal mines in the Eastern Slopes of Alberta have the potential for affecting watershed quality during and following mining. The collection of hydrometric, water quality and hydrometeorologic information is a complex task. A variety of instruments and measurement methods are required to produce a record of hydrologic inputs and outputs for a watershed basin. There is a growing awareness and recognition that standardization of data acquisition methods is required to ensure data comparability, and to allow comparison of data analyses. The purpose of this manual is to assist those involved in the field of data acquisition by outlining methods, practices and instruments which are reliable and recognized by the International Organization for Standardization.

54. **RRTAC 88-9: Computer Analysis of the Factors Influencing Groundwater Flow and Mass Transport in a System Disturbed by Strip Mining. F.W. Schwartz and A.S. Crowe. 78 pp. No longer available.**

Work presented in this report demonstrates how a groundwater flow model can be used to study a variety of mining-related problems such as declining water levels in areas around the mine as a result of dewatering, and the development of high water tables in spoil once resaturation is complete. This report investigates the role of various hydrogeological parameters that influence the magnitude, timing, and extent of water level changes during and following mining at the regional scale. The modelling approach described here represents a major advance on existing work.

55. **RRTAC 88-10: Review of Literature Related to Clay Liners for Sump Disposal of Drilling Wastes. D.R. Pauls, S.R. Moran and T. Macyk. 61 pp. No longer available.**

The report reviews and analyses the effectiveness of geological containment of drilling waste in sumps. Of particular importance was the determination of changes in properties of clay materials as a result of contact with highly saline brines containing various organic chemicals.

56. **RRTAC 88-11: Highvale Soil Reconstruction Project: Five Year Summary. D.N. Graveland, T.A. Oddie, A.E. Osborne and L.A. Panek. 104 pp. $10.00**

This report provides details of a five year study to determine a suitable thickness of subsoil to replace over minespoil in the Highvale plains coal mine area to ensure return of agricultural capability. The study also examined the effect of slope and aspect on agricultural capability. This study was funded and managed with industry assistance.

57. **RRTAC 88-12: A Review of the International Literature on Mine Spoil Subsidence. J.D. Scott, G. Zinter, D.R. Pauls and M.B. Dusseault. 36 pp. $10.00**

The report reviews available engineering literature relative to subsidence of reclaimed mine spoil. The report covers methods for site investigation, field monitoring programs and lab programs, mechanisms of settlement, and remedial measures.

58. **RRTAC 89-1: Reclamation Research Annual Report - 1988. 74 pp. $5.00**

This annual report describes the expenditure of $280,000.00 of Alberta Heritage Savings Trust Fund monies on research under the Land Reclamation Program. The report outlines the objectives and research strategies of the four program areas, and describes the projects funded under each program.

59. **RRTAC 89-2: Proceedings of the Conference: Reclamation, A Global Perspective. D.G. Walker, C.B. Powter and M.W. Pole (Compilers). 2 Vols., 854 pp. No longer available.**

Over 250 delegates from all over the world attended this conference held in Calgary in August, 1989. The proceedings contains over 85 peer-reviewed papers under the following headings: A Global Perspective; Northern and High Altitude Reclamation; Fish & Wildlife and Rangeland Reclamation; Water; Herbaceous Revegetation; Woody Plant Revegetation and Succession; Industrial and Urban Sites; Problems and Solutions; Sodic and Saline Materials; Soils and Overburden; Acid Generating Materials; and, Mine Tailings.

60. **RRTAC 89-3: Efficiency of Activated Charcoal for Inactivation of Bromacil and Tebuthiuron Residues in Soil. M.P. Sharma. 38 pp. ISBN 0-7732-0878-X. $5.00**

Bromacil and Tebuthiuron were commonly used soil sterilants on well sites, battery sites and other industrial sites in Alberta where total vegetation control was desired. Activated charcoal was found to be effective in binding the sterilants in greenhouse trials. The influence of factors such as herbicide:charcoal concentration ratio, soil texture, organic matter content, soil moisture, and the time interval between charcoal incorporation and plant establishment were evaluated in the greenhouse.

61. **RRTAC 89-4: Manual of Plant Species Suitability for Reclamation in Alberta - 2nd Edition. Hardy BBT Limited. 436 pp. ISBN 0-7732-0882-8. $10.00.**

This is an updated version of RRTAC Report 80-5 which describes the characteristics of 43 grass, 14 forb and 34 shrub and tree species which make them suitable for reclamation in Alberta. The report has been updated in several important ways: a line drawing of each species has been added; the range maps for each species have been redrawn based on an ecosystem classification of the province; new information (to 1990) has been added, particularly in the sections on reclamation use; and the material has been reorganized to facilitate information retrieval. Of greatest interest is the performance chart that precedes each species and the combined performance charts for the grass, forb, and shrub/tree groups. These allow the reader to pick out at a glance species that may suit their particular needs. The report was produced with the assistance of a grant from the Recreation, Parks and Wildlife Foundation.

62. **RRTAC 89-5: Battle River Soil Reconstruction Project Five Year Summary. L.A. Leskiw. 188 pp. No longer available.**

This report summarizes the results of a five year study to investigate methods required to return capability to land surface mined for coal in the Battle River area of central Alberta. Studies were conducted on: the amounts of subsoil required, the potential of gypsum and bottom ash to amend adverse soil properties, and the effects of slope angle and aspect. Forage and cereal crop growth was evaluated, as were changes in soil chemistry, density and moisture holding characteristics.

63. **RRTAC 89-6: Detailed Sampling, Characterization and Greenhouse Pot Trials Relative to Drilling Wastes in Alberta. T.M. Macyk, F.I. Nikiforuk, S.A. Abboud and Z.W. Widtman. 228 pp. No longer available.**

This report summarizes a three-year study of the chemistry of freshwater gel, KCl, NaCl, DAP, and invert drilling wastes, both solids and liquids, from three regions in Alberta: Cold Lake, Eastern Slopes, and Peace River/Grande Prairie. A greenhouse study also examined the effects of adding various amounts of waste to soil on grass growth and soil chemistry. Methods for sampling drilling wastes are recommended.

64. **RRTAC 89-7: A User's Guide for the Prediction of Post-Mining Groundwater Chemistry from Overburden Characteristics. M.R. Trudell and D.C. Cheel. 55 pp. $5.00**

This report provides the detailed procedure and methodology that is required to produce a prediction of post-mining groundwater chemistry for plains coal mines, based on the soluble salt characteristics of overburden materials. The fundamental component of the prediction procedure is the geochemical model PHREEQE, developed by the U.S. Geological Survey, which is in the public domain and has been adapted for use on personal computers.

65. **RRTAC 90-1: Reclamation Research Annual Report - 1989. 62 pp. No longer available.**

This annual report describes the expenditure of $480,000.00 of Alberta Heritage Savings Trust Fund monies on research under the Land Reclamation Program. The report outlines the objectives and research strategies of the four program areas, and describes the projects funded under each program.

66. **RRTAC 90-2: Initial Selection for Salt Tolerance in Rocky Mountain Accessions of Slender Wheatgrass and Alpine Bluegrass. R. Hermesh, J. Woosaree, B.A. Darroch, S.N. Acharya and A. Smreciu. 40 pp. $5.00**

Selected lines of slender wheatgrass and alpine bluegrass collected from alpine and subalpine regions of Alberta as part of another native grass project were evaluated for their ability to emerge in a saline medium. Eleven slender wheatgrass and 72 alpine bluegrass lines had a higher percentage emergence than the Orbit Tall Wheatgrass control (a commonly available commercial grass). This means that as well as an ability to grow in high elevation areas, these lines may also be suitable for use in areas where saline soil conditions are present. Thus, their usefulness for reclamation has expanded.

67. **RRTAC 90-3: Natural Plant Invasion into Reclaimed Oil Sands Mine Sites. Hardy BBT Limited. 65 pp. $5.00**

Vegetation data from reclaimed sites on the Syncrude and Suncor oil sands mines have been summarized and related to site and factors and reclamation methods. Natural invasion into sites seeded to agronomic grasses and legumes was minimal even after 15 years. Invasion was slightly greater in sites seeded to native species, but was greatest on sites that were not seeded. Invasion was mostly from agronomic species and native forbs; native shrub and tree invasion was minimal.

68. **RRTAC 90-4: Physical and Hydrological Characteristics of Ponds in Reclaimed Upland Landscape Settings and their Impact on Agricultural Capability. S.R. Moran, T.M. Macyk, M.R. Trudell and M.E. Pigot, Alberta Research Council. 76 pp. $5.00**

The report details the results and conclusions from studying a pond in a reclaimed upland site in Vesta Mine. The pond formed as a result of two factors: (1) a berm which channelled meltwater into a series of subsidence depressions, forming a closed basin; and (2) low hydraulic conductivity in the lower subsoil and upper spoil as a result of compaction during placement and grading which did not allow for rapid drainage of ponded water. Ponds such as this in the reclaimed landscape can affect agricultural capability by: (1) reducing the amount of farmable land (however, the area covered by these ponds in this region is less than half of that found in unmined areas); and, (2) creating the conditions necessary for the progressive development of saline and potentially sodic soils in the area adjacent to the pond.

69. **RRTAC 90-5: Review of the Effects of Storage on Topsoil Quality. Thurber Consultants Ltd., Land Resources Network Ltd., and Norwest Soil Research Ltd. 116 pp. $10.00**

The international literature was reviewed to determine the potential effects of storage on topsoil quality. Conclusions from the review indicated that storage does not appear to have any severe and longterm effects on topsoil quality. Chemical changes may be rectified with the use of fertilizers or manure. Physical changes appear to be potentially less serious than changes in soil quality associated with the stripping and respreading operations. Soil biotic populations appear to revert to pre-disturbance levels of activity within acceptable timeframes. Broad, shallow storage piles that are seeded to acceptable grass and legume species are recommended; agrochemical use should be carefully controlled to ensure soil biota are not destroyed.

70. **RRTAC 90-6: Proceedings of the Industry/Government Three-Lift Soils Handling Workshop. Deloitte & Touche. 168 pp. $10.00**

This report documents the results of a two-day workshop on the issue of three-lift soils handling for pipelines. The workshop was organized and funded by RRTAC, the Canadian Petroleum Association and the Independent Petroleum Association of Canada. Day one focused on presentation of government and industry views on the criteria for three-lift, the rationale and field data in support of three- and two-lift procedures, and an examination of the various soil handling methods in use. During day two, five working groups discussed four issues: alternatives to three-lift; interim criteria and suggested revisions; research needs; definitions of terms. The results of the workshop are being used by a government/industry committee to revise soils handling criteria for pipelines.

71. **RRTAC 90-7: Reclamation of Disturbed Alpine Lands: A Literature Review. Hardy BBT Limited. 209 pp. $10.00**

This review covers current information from North American sources on measures needed to reclaim alpine disturbances. The review provides information on pertinent Acts and regulations with respect to development and environmental protection of alpine areas. It also discusses: alpine environmental conditions; current disturbances to alpine areas; reclamation planning; site and surface preparation; revegetation; and, fertilization. The report also provides a list of research and information needs for alpine reclamation in Alberta.

72. **RRTAC 90-8: Plains Hydrology and Reclamation Project: Summary Report. S.R. Moran, M.R. Trudell, T.M. Macyk and D.B. Cheel. 105 pp. $10.00**

This report summarizes a 10-year study on the interactions of groundwater, soils and geology as they affect successful reclamation of surface coal mines in the plains of Alberta. The report covers: Characterization of the Battle River and Wabamun study areas; Properties of reclaimed materials and landscapes; Impacts of mining and reclamation on post-mining land use; and, Implications for reclamation practice and regulation. This project has led to the publication of 18 RRTAC reports and 22 papers in conference proceedings and referred journals.

73. **RRTAC 90-9: Literature Review on the Disposal of Drilling Waste Solids. Monenco Consultants Limited. 83 pp. $5.00**

This report reviews the literature on, and government and industry experience with, burial of drilling waste solids in an Alberta context. The review covers current regulations in Alberta, other provinces, various states in the US and other countries. Definitions of various types of burial are provided, as well as brief summaries of other possible disposal methods. Environmental concerns with the various options are presented as well as limited information on costs and monitoring of burial sites. The main conclusion of the work is that burial is still a viable option for some waste types but that each site and waste type must be evaluated on its own merits.

74. **RRTAC 90-10: Potential Contamination of Shallow Aquifers by Surface Mining of Coal. M.R. Trudell, S.R. Moran and T.M. Macyk. 75 pp. $5.00**

This report presents the results of a field investigation of the movement of salinized groundwater from a mined and reclaimed coal mine near Forestburg into an adjacent unmined area. The movement is considered to be an unusual occurrence resulting from a combination of a hydraulic head that is higher in the mined area than in the adjacent coal aquifer, and the presence of a thin surficial sand aquifer adjacent to the mine. The high hydraulic head results from deep ponds in the reclaimed landscape that recharge the base of the spoil.

75. **RRTAC 91-1: Reclamation Research Annual Report - 1990. Reclamation Research Technical Advisory Committee. 69 pp. No longer available.**

This annual report describes the expenditure of $499 612 of Alberta Heritage Savings Trust Fund monies on research under the Land Reclamation Program. The report outlines the objectives and research strategies of the four program areas, and describes the projects funded under each program. The report lists the 70 research reports published under the program.

76. **RRTAC 91-2: Winter Soil Evaluation and Mapping for Regulated Pipelines. A.G. Twardy. 43 pp. ISBN 0-7732-0874-7. $5.00**

Where possible, summer soil evaluations are preferred for pipelines. However, when winter soil evaluations must be done, this report lays out the constraints and requirements for obtaining the best possible information. Specific recommendations include: restricting evaluations to the time of day with the best light conditions; use of core- or auger-equipped drill-trucks; increased frequency of site inspections and soil analyses; and, hiring a well-qualified pedologist. The province's soils are divided into four classes, based on their difficulty of evaluation in winter: slight (most soils); moderate; high; and, severe (salt-affected soils in the Brown and Dark Brown Soil Zones).

77. **RRTAC 91-3: A User Guide to Pit and Quarry Reclamation in Alberta. J.E. Green, T.D. Van Egmond, C. Wylie, I. Jones, L. Knapik and L.R. Paterson. 151 pp. ISBN 0-7732-0876-3. $10.00**

Sand and gravel pits or quarries are usually reclaimed to the original land use, especially if that was better quality agricultural or forested land. However, there are times when alternative land uses are possible. This report outlines some of the alternate land uses for reclaimed sand and gravel pits or quarries, including: agriculture, forestry, wildlife habitat, fish habitat, recreation, and residential and industrial use. The report provides a general introduction to the industry and to the reclamation process, and then outlines some of the factors to consider in selecting a land use and the methods for reclamation. The report is <u>not</u> a detailed guide to reclamation; it is intended to help an operator determine if a land use would be suitable and to guide him or her to other sources of information.

78. **RRTAC 91-4: Soil Physical Properties in Reclamation. M.A. Naeth, D.J. White, D.S. Chanasyk, T.M. Macyk, C.B. Powter and D.J. Thacker. 204 pp. ISBN 0-7732-0880-1. $10.00**

This report provides information from the literature and Alberta sources on a variety of soil physical properties that can be measured on reclaimed sites. Each property is explained, measurement methods, problems, level of accuracy and common soil values are presented, and methods of dealing with the property (prevention, alleviation) are discussed. The report also contains the results of a workshop held to discuss soil physical properties and the state-of-the-art in Alberta.

79. **RRTAC 92-1: Reclamation of Sterilant Affected Sites: A Review of the Issue in Alberta. M. Cotton and M.P. Sharma. 64 pp. ISBN 0-7732-0884-4. No longer available**

This report assesses the extent of sterilant use on oil and gas leases in Alberta, identifies some of the concerns related to reclamation of sterilant affected sites and the common methods for reclaiming these sites, and outlines the methods for sampling and analyzing soils from sterilant affected sites. The report also provides an outline of a research program to address issues raised by government and industry staff.

80. **RRTAC 92-2: Reclamation Research Annual Report - 1991. Reclamation Research Technical Advisory Committee. 55 pp. ISBN 0-7732-0888-7. No longer available.**

This report describes the expenditure of $485,065 of Alberta Heritage Savings Trust Fund monies on research under the Land Reclamation Program. The report outlines the objectives and research strategies of the five program areas, and describes the projects funded under each program. It also lists the 75 research reports that have been published to date.

81. **RRTAC 92-3: Proceedings of the Industry/Government Pipeline Reclamation Success Measurement Workshop. R.J. Mahnic and J.A. Toogood. 62 pp. ISBN 0-7732-0886-0. $5.00.**

This report presents the results of a workshop to identify the soil and vegetation parameters that should be used to assess reclamation success on pipelines in Alberta. Six soil parameters (topsoil admixing; topsoil replacement thickness; compaction; soil loss by erosion; texture; and salinity) and six vegetation parameters (plant density; species composition; ground cover; vigour; weeds/undesirable species; and rooting characteristics) were selected as most important. Working groups discussed these parameters and presented suggested methods for assessing them in the field.

82. **RRTAC 92-4: Oil Sands Soil Reconstruction Project Five Year Summary. HBT AGRA Limited. 109 pp. ISBN 0-7732-0875-5. $10.00**

This report documents a five year study of the effects of clay and peat amendments to oil sand tailings sand on survival and growth of trees and shrubs. Ten species (jack pine, white spruce, serviceberry, silverberry, buffaloberry, pin cherry, prickly/woods rose, Northwest poplar, green alder, and Bebb willow) were planted into tailings sand amended with three levels of peat and three levels of clay. The treatments were incorporated to a depth of 20 cm or 40 cm. Data are provided on plant survival and growth, root size and distribution, disease and small mammal damage, herbaceous cover, soil moisture, soil chemistry, and bulk density.

83. **RRTAC 92-5: A Computer Program to Simulate Groundwater Flow and Contaminant Transport in the Vicinity of Active and Reclaimed Strip Mines: A User's Guide. A.S. Crowe and F.W. Schwartz, SIMCO Groundwater Research Ltd. 104 pp. plus appendix. ISBN 0-7732-0877-1. NOTE: This report is only available from the Alberta Research Council, Publications Centre, 250 Karl Clark Road, P.O. Box 8330, Station F, EDMONTON, Alberta T6H 5R7 as ARC Information Series 119. The cost is $20.00 and the cheque must be made out to the Alberta Research Council.**

The manual describes a computer program that was developed to study the influence of coal strip mining on groundwater flow systems and to simulate the transport of generated contaminants, both spatially and in time, in the vicinity of a mine. All three phases of a strip mine can be simulated: the pre-mining regional groundwater flow system; the mining and reclamation phase; and, the post-mining water level readjustment phase. The model is sufficiently general to enable the user to specify virtually any type of geological conditions, mining scenario, and boundary conditions.

84. **RRTAC 92-6: Alberta Drilling Waste Sump Chemistry Study. Volume I: Report (Volume II: Appendices is only available through the Alberta Research Council, Publications Centre, 250 Karl Clark Road, P.O. Box 8330, Station F, EDMONTON, Alberta T6H 5R7. The cost is $15.00 and the cheque must be made out to the Alberta Research Council.). T.M. Macyk, S.A. Abboud and F.I. Nikiforuk, Alberta Research Council. 217 pp. ISBN 0-7732-0879-8. $10.00.**

This study synthesizes the data from sampling and analysis of the solids and liquids found in 128 drilling waste sumps across Alberta. Drilling waste types sampled included: 72 freshwater gel, 19 invert, 27 KCl, 2 NaCl, and 8 others. Data and statistics are tabulated by waste type, depth of the drill hole, and ERCB administrative region for both the solids and the liquids. Using preliminary loading limits developed by the government/industry Drilling Waste Review Committee, the report presents information on the volume and depth of waste that could be landspread, and the area required for landspreading. The oil and gas industry provided approximately $585,000 for the sampling and analysis phase of this study.

85. **RRTAC 93-1: Reclamation of Native Grasslands in Alberta: A Review of the Literature. D.S. Kerr, L.J. Morrison and K.E. Wilkinson, Environmental Management Associates. 205 pp. plus appendices. ISBN 0-7732-0881-X. $10.00.**

A review of the literature on native grassland reclamation was conducted to summarize the current state of knowledge on reclamation and restoration efforts within Alberta. The review is comprehensive, including an overview of the regulations and guidelines governing land use on native prairie; a description of the dominant grassland ecoregions in Alberta; a review of the common disturbance types, extent and biophysical effects of disturbance on native prairie within Alberta; a description of the factors which influence the degree of disturbance and reclamation; and examples of both natural and enhanced recovery of disturbed sites through the examination of selected case studies.

86. **RRTAC 93-2: Reclamation Research Annual Report - 1992. Reclamation Research Technical Advisory Committee. 56 pp. ISBN 0-7732-0883-6. $5.00.**

This report describes the expenditure of $474,705 of Alberta Heritage Savings Trust Fund monies on research under the Land Reclamation Program. The report outlines the objectives and the research strategies of the five programs, and describes the projects funded under each program. It also lists the 85 research reports that have been published to date.

87. **RRTAC 93-3: Catalogue of Technologies for Reducing the Environmental Impact of Fine Tailings from Oil Sand Processing. B.J. Fuhr, Alberta Research Council, D.E. Rose, Dereng Enterprises Ltd., and D. Taplin, Komex International Ltd. 63 pp. ISBN 0-7732-0885-2. $5.00.**

A catalogue containing 22 technologies for reducing the environmental impact of fine tailings derived from oil sands has been assembled. The report consists of an introduction to oil sand processing and fine tailings generation, a simple spreadsheet for comparing the technologies, and a process summary for each technology. The technologies were not evaluated for effectiveness. Rather, a detailed set of questions was prepared that highlights the environmentally-related information a proponent should have. These questions will help to form a basis for comparisons among the technologies.

88. **RRTAC 93-4: Organic Materials as Soil Amendments in Reclamation: A Review of the Literature. Land Resources Network Ltd. 228 pp. ISBN 0-7732-0887-9. $10.00**

A review of the literature was conducted to examine the effect of various organic materials when used as amendments to disturbed soil. Organic amendments reviewed included animal manures, crop residues, peat, wood wastes, sewage sludge, municipal yard waste, humates, vermicomposts, and spent mushroom composts. Their effects on soil chemistry, physical properties, and biology were examined. Application methods, costs, longevity of effects, and use in reclamation were also reviewed. Benefits and drawbacks of each were discussed.

89. **RRTAC 93-5: Drilling Waste Disposal. T.M. Macyk and S.A. Abboud, Alberta Research Council. 125 pp. ISBN 0-7732-0889-5. $10.00**

An overall perspective and description of the steps involved in the management and land-based disposal of drilling wastes in Alberta. A computer program, available from the Alberta Research Council, has been written to support the data management required for proper disposal. A field manual is in preparation. These three information sources provide technical support for the Energy Resources Conservation Board's Guide G-50: Drilling Waste Management.

90. **RRTAC 93-6: Mapping and Characterization of Cutover Peatlands for Reclamation Planning. L.W. Turchenek, Alberta Research Council, W.S. Tedder, Alberta Agriculture, Food and Rural Development, and R. Krzanowski, Alberta Research Council. 100 pp. ISBN 0-7732-6038-2. $5.00**

The report presents a methodology for cost-effective soil survey and sampling of cutover peatlands. It also presents baseline chemical information and data interpretation for peat materials from a cutover peatland site. The report provides background information on classifying and describing peatlands. This information can be used to develop reclamation plans.

91. **RRTAC 93-7: Soil Series Information for Reclamation Planning in Alberta. Pedocan Land Evaluation Ltd. Various pagings. ISBN 0-7732-6041-2. $10.00**

This manual has been published to provide conservation and reclamation planners with information and guidelines to help understand and use soil inventory data. The soil series in the manual correspond to those in the Generation 2 Alberta Soil Names File. Part 1 of the manual describes the terminology used in soil surveys and presents the assumptions and conventions upon which the interpretations for each soil series are based. Part 2 presents typical data and interpretations for each soil series.

92. **RRTAC 93-8: Oils Sands Sludge Dewatering by Freeze-Thaw and Evapotranspiration. R. L. Johnson, P. Bork. W. H. James and L. Koverny. 247 pp. ISBN 0-7732-6042-0. $10.00**

This report presents data from a series of laboratory and field experiments designed to evaluate the removal of water from oil sands sludge. A number of plant species were evaluated and two, reed canary grass and western dock, were found to remove a significant amount of water through evapotranspiration. Freeze-thaw cycles were also found to remove water from both sand-sludge mixtures and pure sludge. A combination of freeze-thaw and biological dewatering using plants was found to increase solids content from 30% to 80%. At 80% solids the sludge had a shear strength of 120 kPa and could support machine traffic. These studies prompted further field work.