Of General Interest

- ☞ **Appendix A. Interactive forum attendees**
- ☞ **Appendix B. Field tour of Peabody Western Coal Company's Black Mesa/Kayenta mine complex**
- ☞ **Appendix C. Plants for Western land reclamation (1994 edition)**
- ☞ **Appendix D. Contact and web-page listings: Noxious weed control in coal-mining regions of the West**
- ☞ **Appendix E. A guide to noxious weeds of the Navajo Reservation**
- ☞ **Appendix F. A guide to noxious weeds of the Centralia mine, Washington State**
- ☞ **Appendix G. Breeding and selection of superior plants for use in reclamation**

Appendix A

Interactive Forum Attendees

Purple prairieclover
Dalea purpurea

"Interactive Forum Attendees"

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Appendix B

Field Tour of Peabody Western Coal Company's Black Mesa/Kayenta Mine Complex

Galleta
Hilaria jamesii

"Field Tour of Peabody Western Coal Company's
Black Mesa/Kayenta Mine Complex"

September 25, 1999, Saturday, 8am-5pm - **Field Tour**

Peabody Western Coal Company's Black Mesa/Kayenta Mine Complex

Participants observed current mining and reclamation operations at the Black Mesa/Kayenta Coal Mine Complex located on Black Mesa in Northern Arizona. Of particular interest was the ongoing work in establishing culturally significant native plants on reclaimed lands. Established stands and recently seeded areas were visited. The visit offered an opportunity to discuss identification and collection of culturally significant native plant species and the various techniques that have been used to establish them on the mine.

Navajo blue pollen —

"Larkspur" seeds used in the cultural plant program are collected from the Black Mesa. Using seed resources that are genetically adapted to the area helps ensure better growth and survival. Navajo blue pollen, which is used in ceremonies, is among more than 60 culturally significant species targeted for re-establishment on reclaimed lands.

Russian rye —

Reclaimed lands at the Black Mesa complex typically support 20 times more livestock than native range and feature a diverse mixture of warm and cool season grasses, forbs and woody plants that average about 450 pounds per acre.

Pinon —

Technology for re-establishing traditional plants has been improved dramatically at Peabody Energy's Arizona mines, resulting in better plant survival. Procedures include nursery practices that maximize the potential for survival such as specific seed treatment, germination methods and fungi inoculation.

Appendix C

Plants for Western Land Reclamation
(1994 Edition)

Scarlet globemallow
Sphaeralcea coccinea

"Plants for Western Land Reclamation
(1994 Edition)"

Plants

for

Western Land Reclamation

1994 Edition

New Mexico
Energy, Minerals and Natural Resources Department
Mining and Minerals Division
Prepared by Joe DeAguero

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Introduction

The purpose of this handbook is to assist people involved in the revegetation aspect of disturbed land reclamation. Included in this handbook Is Information about reclamation plant species and their growing conditions. Since there are constant new technologies and methods of using reclamation procedures that make common practices outdated, there Is a constant need to update current practices and knowledge.

This handbook contains information regarding vegetative characteristics that describe grass, forb, shrub and trees. Also contained, are identification sheet that individually describe commercially available plants being used in land reclamation. Each identification sheet contains the plants common name, genus and species, general information, identification growing conditions and reclamation benefits.

Updated information has been added to this edition that includes identification information of weed species, general guidelines for soil and nutrient suitability and a general seed mix. In addition, several other species have been added to the ever expanding list of tolerant species.

Changes to this handbook will be necessary as reclamation procedures and practices improve and new plant materials, technology and new practices are used in disturbed land reclamation.

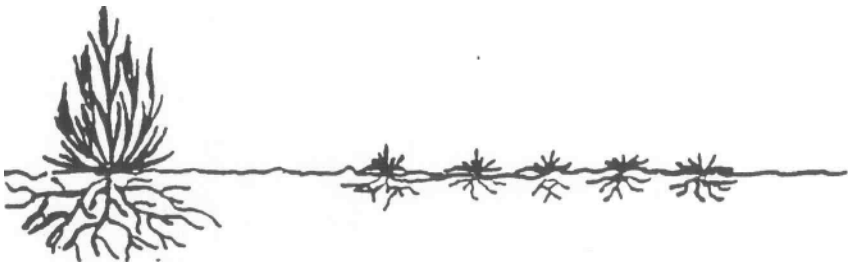
Vegetative Characteristics

Cool Season Grasses are described as plants that develop vegetative and reproductive parts during the cooler part of the growing year.

Warm Season Grasses are described as plants that develop vegetative and reproductive parts during the warm or hot part of the growing year.

Bunch Grasses are generally growing in a clump, spreading by lateral shoots known as tillers. Commonly deeply rooted. Perennial grasses often have rhizomes.

Sod -Forming Grasses are matted plants often spreading by stolons and/or rhizomes.

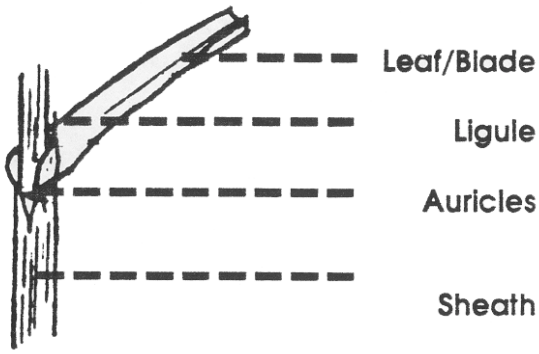


Bunch Grass **Sod-Former**

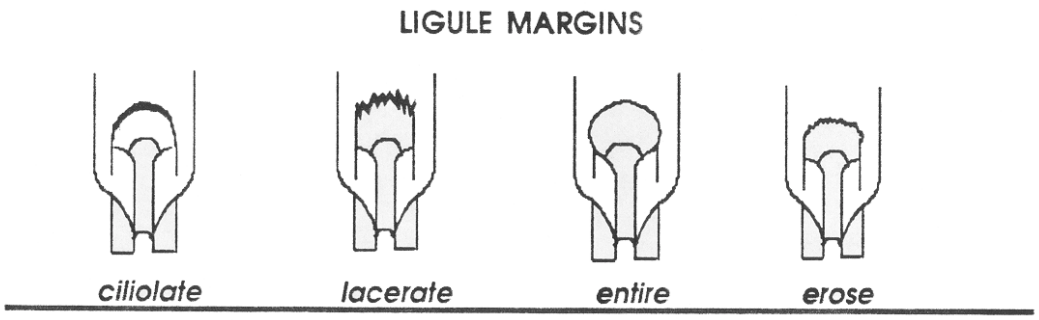
Rhizomes are underground stems, with nodes where rooting and budding occurs.

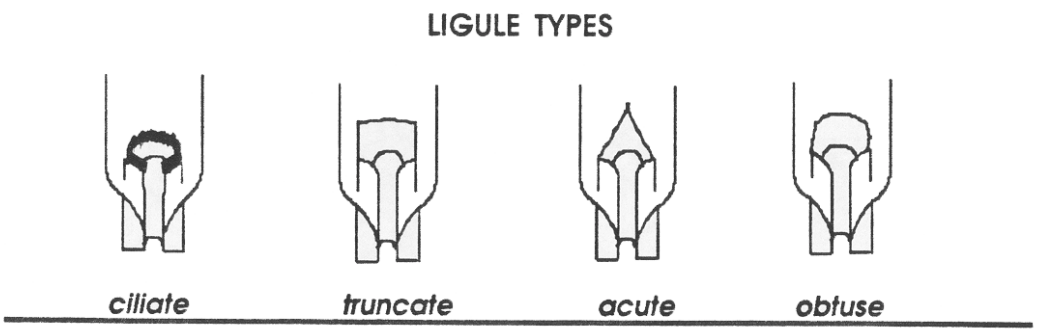
Stolons are stems spreading laterally above ground. Rooting and developing shoots at the nodes.

Leaf/ Blade often gives many identifiable characteristics such as color, roughness, size and form that will assist in the identification of many grasses, forbs and shrubs. See glossary for specific leaf descriptions.



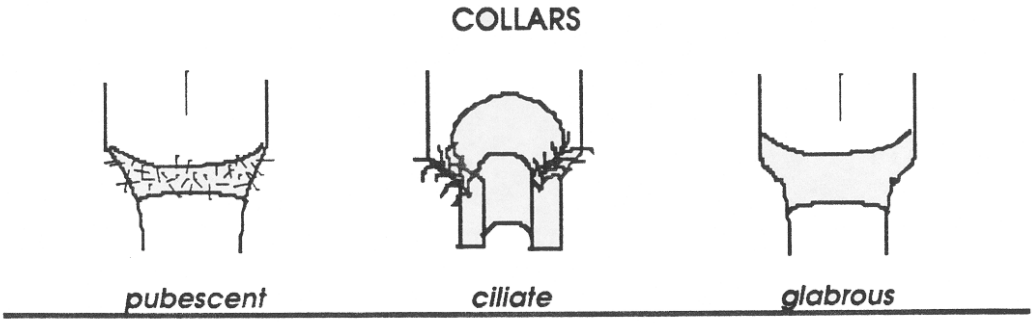
Ligules are often a most useful characteristic to identify grass plants. Located at the base of the blade, they are most often dilate or membranous. The following are examples of ligule types and margins.



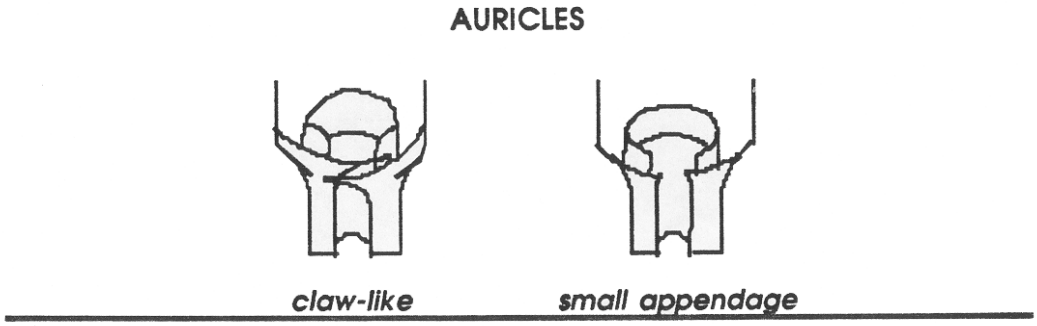


Sheaths are located at the lower section of the blade. Closed, overlapping or open creating a tube structure know as the stem. See examples below,

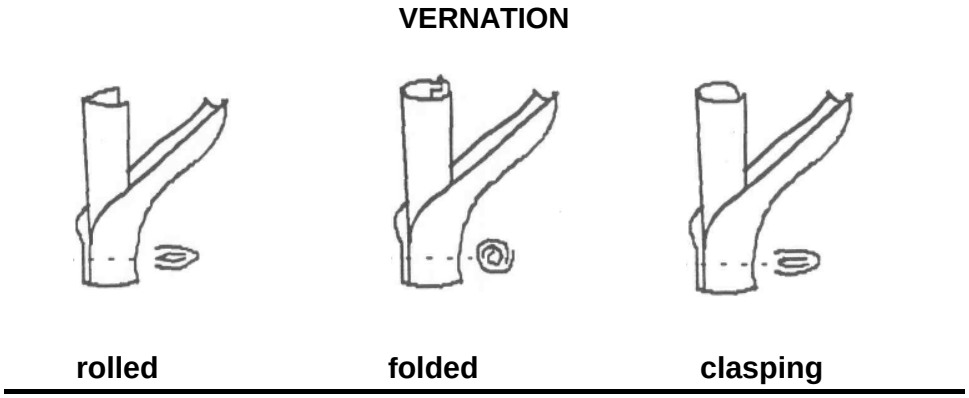
Collars are bands present where the blade and sheath meet at the base of the blade. Collars are clearly present in some grasses and inconspicious in others. The following are examples of collars.



Auricles are extensions of the edges of the collar that appear claw-like or as a small appendage. Often occuring only on one side of the collar.



Vernation describes the cross-section form of the leaf as it develops. Commonly folded, rolled or clasping.



Species Characteristics

Grasses

Cool Season Species

Thickspike wheatgrass	*Agropyron dasystachyum*
Western wheatgrass	*Agropyron smithii*
Slender wheatgrass	*Agropyron trachycaulum*
Red Top	*Agrostis alba*
Little bluestem	*Andropogon scoparius*
Cheatgrass	*Bromus tectorum*
Mountain brome	*Bromus marghatus*
Pine dropseed	*Blepharoneuron tricholepis*
Orgachard grass	*Dactylis glomerata*
Canada wildrye	*Elymus canadensis*
Great Basin wildrye	*Elymus cinereus*
Sand lovegrass	*Eragrostis trichodes*
Arizona fescue	*Festuca arizonlca*
Idaho fescue	*Festuca Idahoensis*
Sheep fescue	*Festuca ovina*
Foxtail barley	*Hordeum jubatum*
Mountain muhly	*Muhlenbergia montana*
Spike muhly	*Muhlenbergia wrightii*
Indian ricegrass	*Oryzopsis hymenoides*
Reed canary grass	*Phalaris arundinacea*
Kentucky bluegrass	*Poa pratensis*
Sandburg bluegrass	*Poo sandbergii*
Blue bunch wheatgrass	*Pseudoroegnerla splcata*
Needle and thread	*Stipa comata*
Green needlegrass	*Stipa vlridula*

Warm Season Species

Big bluestem	*Andropogon gerardii*
Sideoats grama	*Bouteloua curtlpendula*
Black grama	*Bouteloua eripoda*
Blue grama	*Bouteloua gracllis*
Prairie sandreed	*Calamouilfa longifolia*
Galleta	*Hillara jamesii*
June grass	*Koeleria cristata*
Switchgrass	*Pancium virgatum*
Alkali sacaton	*Sporobolus airoldes*
Sand dropseed	*Sporobolus cryptandrus*

Sod Forming Species

Thickspike wheatgrass	*Agropyron dasystachyum*
Western wheatgrass	*Agropyron smithii*
Red Top	*Agrostis alba*
Big bluestem	*Andropogon gerardlt*
Sideoats grama	*Bouteloua curtipendula*
Blue grama	*Bouteloua gracilis*
Prairie sandreed	*Calamouilfa longifolta*
Sand lovegrass	*Eragrostis trichodes*
Galleta	*Hilaria J*amesii*
Foxtail barley	*Hordeum jubaturm*
Kentucky bluegrass	*Poa pratensis*

**** A bunchgrass under non-grazed conditions.***

Bunch Forming Species

Slender wheatgrass	*Agropyron trachycaulum*
Little bluestem	*Andropogn scoparllus*
Pine dropseed	*Blepharoneuron tricholepls*
Sideoats grama	*Bouteloua curtipendula**
Blue grama	*Bouteloua gracilis**
Mountain brome	*Bromus marginatus*
Orchard grass	*Dactylis glomerata*
Canada wildrye	*Eylmus canadensis*
Great basin wildrye	*Elymus clnereus*
Idaho fescue	*Festuca Idahoensls*
Sheep fescue	*Festuca ovina*
Galleta	*Hilaria jamesii**
June grass	*Koeleria cristata*
Mountain muhly	*Mulenbergia montana*
Indian ricegrass	*Oryzopsis hymenoides*
Switchgrass	*Panclum vlrgatum*
Reed canary grass	*Phalaris arundinacea*
Sandburg bluegrass	Poo *sandbergii*
Bluebunch wheatgrass	*Pseudoroegneria splcata*
Alkali sacaton	*Sporobolus airoldes*
Sand dropseed	*Sporobolus cryptandrus*
Needle and thread	*Stipa comata*
Green needlegrass	*Stlpa viridula*

*** A sod-former under g:vzed conditions.**

Species Adapted to All Soils

Grasses

Slender wheatgrass	*Agropyron trachycaulum*
Redtop	*Agrostis alba*
Big bluestem	*Andropogon gerardil*
Little bluestem	*Andropogn scoparius*
Sideoats grama	*Bouteloua curtipendula*
Orchard grass	*Dactylis glomerata*
Canada wildrye	*Elymus canadensis*
Idaho fescue	*Festuca idahoensis*
Galleta	*Hilaria jamesii*
Foxtail barley	*Hordeum jubatum*
Mountain muhly	*Muhlenbergia montana*
Spike muhly	*Muhlenbergia wrightli*
Sandburg bluegrass	*Poa sandbergii*
Bluebunch wheatgrass	*Pseudoroegneria spicata*

Forbs

Aster spp	*Aster spp*
Cicer milkvetch	*Astragalus deer*
Winged wild buckwheat	*Ergonum alatum*
Alfalfa rhizoma	*Medicago sativa*
Yellow sweetclover	*Melllotus offlclnalis*

Shrubs

Fourwing saltbush	*Atriplex canescens*
Shadscale	*Atriplex confertlfolia*
Winterfat	*Ceratoldes lanata*
Mountain mahogany	*Cercocarpus montanus*
Cliffrose	*Cowanla mexlcana*
Antelope bitterbrush	*Purshia tridentata*

Trees

Utah juniper	*Junlperus osteosperma*
Ponderosa Pine	*Pinus Ponderosa*
Gamble Oak	*Quercus gambeiii*

Species Adapted to Clay Soils

Grasses

Western wheatgrass	*Agropyron smtthll*
Redtop	*Agrostls alba*
Big bluestem	*Andropogon gerardil*
Blue grama	*Boufeloua gradlis*
Mountain brome	*Bromus marginatus*
Great basin wildrye	*Elymus clnereus*
Idaho fescue	*Festuca idahoensis*
Galleta	*Hilarla jamesil*
Switchgrass	*Pancium vlrgatum*
Reed canary grass	*Phalaris arundlnacea*
Kentucky bluegrass	*Poa pratensis*
Alkali sacaton	*Sporobolus airoides*
Green needlegrass	*Stipa viridula*

Forbs

Pacific aster	*Aster adscendens*
Wooly yarrow	*Achlllea lanulosa*
Fringed sagebrush	*Artemisla frlgida*
Prairie sagebrush	*Artemlsla ludoviclana*
Cicer milkvetch	*Astragalus clcer*
Rocky mountain iris	*Iris mlssouriensis*
Mexican hat	*Ratibida columnifera*

Shrubs

Utah serviceberry	*Amelanchier utahensls*
Nuttall saltbush	*Atriplex nuttallii*
Douglas rabbit brush	*Chrysothamnus vlscldiflorus*
Wax currant	*Ribes cereum*
Fendler rose	*Rosa woodsii*

Species Adapted to Sandy Soils

Grasses

Thickspike wheatgrass	*Agropyron dasystcchyum*
Sideoats grama	*Bouteloua curtipendula*
Black grama	*Bouteloua eripoda*
Prarie sandreed	*Calamouilfa longifolia*
Sand lovegrass	*Eragrostls trtchodes*
Arizona fescue	*Festuca arizonlca*
Sheep fescue	*Festuca ovina*
Galleta	*Hilaria jamesii*
Indian ricegrass	*Oryzopsls hymenoides*

Blue bunch wheatgrass

Little bluestem	*Pseudoroegneria spicata*
Sand dropseed	*Schizachyrium scoparius*
Needle and thread	*Sporobotus cryptandrus*
	Stipa comata

Forbs

Blue flax	*Unum lewisll*
Alfalfa rhizoma	*Medicago sativa*
Yellow sweetclover	*Melilotus offidnalis*
Rocky mountain penstemon	*Penstemon strictus*
Purple prairie clover	*Petalostemon purpureum*

Shrubs

Fourwing saltbush	*Atrlplex canescens*
Rubber rabbit brush	*Chrysothamnus nauseosus*
Douglas rabbit brush	*Chrysothamnus vlscldiflorus*
Common choke cherry	*Prunus virglniana*
Antelope bitterbrush	*Purshta trldentata*
Skunk bush sumac	*Rhus trilobate*
New Mexico locust	*Roblnla neomexicana*
Western snowberry	*Symphoricarpos occidentalis*

Trees

New Mexico Olive	*Forestiera neomexicana*

Drought Tolerant Species

Grasses

Thickspike wheatgrass	Agropyron dasystact-vum
Western wheatgrass	Agropyron smithii
Slender wheatgrass	Agropyron trachycaulum
Pine dropseed	Blepharoneuron tricholepis
Sideoats grama	Bouteloua curtlpendula
Black grama	Bouteloua eripoda
Blue grama	Bouteloua gradlis
Prairie sandreed	Calamouilfa longifolla
Orchard grass	Dactylls glomerata
Canada wildrye	Elymus canadensis
Sand lovegrass	Eragrostis trichodes
Arizona fescue	Festuca arizonlca
Idaho fescue	Festuca idahoensls
Sheep fescue	Festuca ovina
Galleta	Hilaria jamesii
Indian ricegrass	Oryzopsis hymenoides
Sandburg bluegrass	Poa sandbergii
Bluebunch wheatgrass	*Pseudoroegneria splcata*

Little bluestem	*Schlzachyrium scoparlus*
Alkali sacaton	*Sporobolus airoldes*
Sand dropseed	*Sporobolus cryptandrus*
Needle and thread	*Stipa comata*
Green needlegrass	*Stipa viridula*

Forbs

Fringed sagebrush	*Artemisla frigida*
Prairie sagebrush	*Artemisia ludoviciana*
Aster spp.	*Aster spp.*
Mat Saltbush	*Atrtplex Corrugata*
Winged wild buckwheat	*Erigonum alatum*
Blue flax	*Linum lewisii*
Yellow sweetclover	*Melllotus offlcinalis*
Hookers Evening Primrose	*Oenothera hookeiii*
Mexican hat	*Ratiblda columnlfera*
Globemallow	*Sphaeralcea cocclnea*

Shrubs

Fourwing saltbush	*Atriplex canescens*
Shadscale	*Atriplex confertlfolla*
Nuttall saltbush	*Atriplex nuttallii*
Broadscale	*Atrlplex obovata*
Winterfat	*Ceratoldes lanata*
Mountain mahogany	*Cercocarpus montanus*
Rubber rabbit bush	*Chrysothamnus nauseosus*
Douglas rabbitbrush	*Chrysofhamnus viscldiflorus*
Cliffrose	*Cowanla mexicana*
Antelope bitterbrush	*Purshla trldentata*
Wax currant	*Ribes cereum*

Trees

New Mexico olive	*Forestiera neomexicana*
Utah juniper	*Juniperus osteosperma*
Pinon pine	*Pinus edulis*
Ponderosa Pine	*Pinus Ponderosa*

Salt (saline) Tolerant Species

Grasses

Western wheatgrass	*Agropyron smithii*
Slender wheatgrass	*Agropyron trachycaulum*
Blue grama	*Bouteloua gracilis*
Mountain brome	*Bromus marginatus*
Canada wildrye	*Elymus wildrye*

Great basin wildrye	*Elymus cinereus*
Galleta	*Hilaria jamesii*
Foxtail barley	*Hordeum jubatum*
Alkali sacaton	*Sporobolus airoides*

Forbs

Fringed sagebrush	*Artemmisia frigida*
Prairie sagebrush	*Artemisia ludoviclana*
Yellow sweetclover	*Melilotus officinalis*

Shrubs

Fourwing saltbush	*Atriplex canescens*
Shadscale	*Atriplex confertifolta*
Mat saltbush	*Atrlplex corrugate*
Nuttall saltbush	*Atriplex nuttallll*
Broadscale	*Atrlplex obovata*
Winterfat	*Ceratoldes lanata*
Rubber rabbit brush	*Chrysothamnus nauseosus*
Douglas rabbitbrush	*Chrysothamnus viscldiflorus*
Black greasewood	*Sarcobatus vermiculatus*

Vegetation Identification and Adaptive Information

Vegetation identification and adaptive information sheets are designed to describe plant characteristics for identification, growing conditions and reclamation benefits of plant for land reclamation.

Identification provides information such as growing season, leaf size, seedhead shape, type of root system and other important characteristics used in plant identification.

Growing Conditions lists a plant's tolerance to drought, alkalinity, acidity saline and sodic condition or other tolerance. Also the list includes the soil texture the plant is adapted to; the precipitation zone recommended and often the elevation at which it naturally occurs.

Reclamation Benefits for wildlife, domestic livestock, nutrition, portability, tolerance to grazing and other uses such as erosion control are identified here.

Arrangement of plant species will be alphabetical by Genus name. Order of plant type will be grasses, forbs, shrubs, trees and weeds respectively.

Notes

Thickspike Wheatgrass
Agropyron dasystachyum

- **Cool season**
- **Sod-former**
- **Mid-grass**
- **186,000 seeds/lb.**
- **Adapted Varieties: "Critana"**

Identification

Leaf: Narrow, 1 to 6 mm wide, usually involute and scabrous,mostly green but often blue-green with less conspicuous upper surface veins. 5 to 25 cm long.

Seedhead: Inflorescence erect, terminal spike up to 8 Inches long. Spikelets irregularly flattened toward spike's axis, plump and divergent, 0.5" long and 3 to 8 flowered. Glumes broadest at or above middle. Pubescent and acute-tipped. Lemmas hairy.

Roots: Widely spreading rhizomes, that are somewhat shallow.

Ligule: Membranous, Truncate to obtuse, often lacerate, to 1mm long.

Sheath: Roung, smooth and open, margin often ciliate, white to pinkish below or near ground level.

Collar: Continuous, and red-tinged. Rolled vernation.

Growing Conditions

- Prefers sandy or gravelly soils.
- Tolerant of weakly saline soils.
- Good drought tolerance.
- Recommended in the 6 to 20 inch precipitation zone.
- Excellent seedling vigor; strong sod-former, and good seed producer.

Reclamation Benefits

- Useful for early spring grazing.
- Good for soil stabilization of disturbed lands.
- Wildlife planting in the semi-desert and upland climatic zones.

Notes

Western Wheatgrass
Agropyron smithii

- Cool season
- **Sod-former**
- **Native perennial**
- **110,000 seeds/lb.**
- **1' to 3' tall**
- **Adapted Varieties: "Ariba"**

Identification

Leaf: Coarse blue-green leaves with prominent veins. Auricled blades 2 to 6 mm wide, 5 to 25 cm long. Stiff, flat, drying involute. Auricles purplish when mature.

Seedhead: Spike is stiff, erect and about 2 to 6 inches long. Produces seed in June. Wheat-like inflorescens.

Roots: Very strong spreading rhizomes.

Ligule: Membranous, truncate, ciliolate to 1 mm long.

Sheath: Open, glabrous, brown or purplish at base.

Collar: Divided, smooth, indistinct.

Growing Conditions

- Adapted to fine and very fine soils; does best in heavy, well drained soils.
- Tolerant to poor drainage.
- Tolerant to saline and saline-sodic soils.
- Tolerant to moderately severe droughts.
- Moderate to high soil moisture is needed for best growth, common in 10"-14" precipitation zone.
- Pitting, chiselling, and discing will stimulate stands.

Reclamation Benefits

- Palatable to deer only in spring.
- Palatable to elk and cattle all year. Quality of forage diminish during late summer.
- Can be grazed to 3" to 4" of stubble.

Notes

Slender Wheatgrass
Agropyron trachycaulum

- **Cool season**
- **Bunchgrass**
- **Native perennial**
- **160.000 seeds/lb.**
- **1' to 2' tall**
- **Adapted Varieties:**
  "Revenue"
  "Primar"

Identification

Leaf: 2 to 4 rnm wide, 5-25 cm long, flat to involute with whitish margins, auricles short and slender. Upright culm.

Seedhead: 8 to 20 cm long spike, slender; spikelets 3 to 7 flowered; glumes, acute or awn pointed; lemmas glabrous, faintly nerved. Flowering June to October.

Roots: Rhizomes absent.

Ligule: Membranous, truncate, finely ciliolate, 0.5 to 1 mm long.

Sheath: Round, open.

Collar: Medium broad, distinct, yellow-green, continuous and glabrous,

Growing Conditions

- Adapted to all soil textures, medium to clayey textures best,
- Fair to good salt and sodic tolerance.
- Rarely found in shady areas
- 18" to 22" precipitation zone.
- Fair to good drought tolerance.
- Widespread, 5,000 to 11.000 ft.
- A short lived pioneer species, first to dominate stand.
- Found in riparian areas if not flooded.

Reclamation Benefits

- Mule deer graze lightly winter and spring.
- Not tolerant to close grazing.
- Portability varies from low to high.
- Palatable and used in large amounts by livestock.

Notes

Redtop
Agrostis alba

- ○ **Introduced species**
- ○ **Cool season**
- ○ **4,900,000 seeds/lb**
- ○ **Sod-former**
- ○ **Perennial**

Identification

Leaf: Blades are flat, 5 to 10 mm wide.

Seedhead: Culms sometimes can be as much as 1 to 1.5 m. tall, the base erect or decumbent. Panicle 5 to 30 cm long, 5 to 50 mm wide, pyramidal to ovate; branches spreading or ascending to oppressed, densely flowered, purplish to reddish; lower panide branches whorled, branches not densely flowering a; oase, flowering nodes reddish.

Roots: Strong creeping rhizomes

Ligule: Membranous 1 to 7 mm long, acute, erose.

Sheath: Round, glabrous, frequently purplish to reddish.

Growing Conditions

- Adapts well to nutritionally poor, acid sites low In calcium.
- Establishes well after a disturbance, but not shade tolerant.
- May lack winter hardiness on exposed sites.
- Requires more moisture than is generally available on the Great Plains.
- Some populations reveal metal tolerances.
- Found in run-in areas of moist or more mesic grasslands, pastures, and meadows or along stream banks.

Reclamation Benefits

- Relatively easy to establish from seed or vegetatlvely, seedling of average vigor.
- Spreads well in the field by roots, rhizomes or by development of roots from nodes of decumbent stems.
- Long lived.
- Widely used for erosion control in more mesic areas especially when soils are acidic.

Notes

Big Bluestem
Andropogon gerardii

- ○ Sod-former
- ○ **Warm season**
- ○ **130,000 seeds/lb.**
- ○ **Native perennial grass**

Identification

Leaf: Blades are flat, elongate, mostly 5 to 10 mm wide, the margins very scabrous.

Seedhead: Panicle of 2 to 6, commonly 3, digitate or subdigitate racemose primary branches that are 4 to 11 cm long. Fewer than 10 per culm; often purplish and sometimes yellowish. Lemma of sessile spikelet owned 1 to 2 cm long, geniculate and tightly twisted below.

Auricles: Rudimentary.

Ligule: Short ciliate membrane 0.4 to 2.5 mm long.

Sheath: Compressed, purplish at base, lower sheaths sometimes villous, margins hyaline.

Growing Conditions

- Grows rapidly from mid-spring to early fall, numerous leaves produced in late spring and early summer.
- Growing points stay near ground level until late summer, reproduces primarily from rhizomes.
- Adapted to all soil textures.
- Most abundant in lowland prairies, with high moisture.
- Frequently seeded.

Reclamation Benefits

- Excellent and highly palatable to all classes of livestock when grazed or in hay, commonly consumed in preference to other grasses on summer range, becomes coarse late in the season.
- Can be used for erosion control.
- Used In moist overflow sites.

Notes

Little Bluestem
Andropogon scoparius

- **Warm season**
- **Bunchgrass**
- **Native perennial**
- **225,000 seeds/lb.**
- **V to 2'tall**
- **Adapted Varieties:**
  "Aldous"
  "Blaze"
  "Pasture"

Identification

Leaf: 3 to 7 mm wide, 5 to 25 mm long; blade folded occasionally, flat scabrous upper surface and margins,
smooth bottom, prominent midvein.

Seedhead: "Trashy", seeds alternately spaced on stalk, pilose.

Roots: Dense, spreads by tillering and by short rhizomes, Also spreads by seeds.

Ligule: Membranous, obtuse, toothed .05 to 2 mm long.

Sheath: Open, compressed-keeled.

Collar: Continous, broad, glabrous. Folded vernation.

Growing Conditions

- Best on well drained, course textured soils.
- Adapted to all soil textures,
- Poor tolerance to saline soils.
- Recommended in the 10" to 16' precipitation zone.
- Fair to good drought tolerance.
- For use on low fertility soils.

Reclamation Benefits

- Moderate to high portability.
- Use on revegetation of roads and construction areas.
- Valuable to wildlife grazing.
- Highly palatable to livestock during spring and early summer.

Notes

Pine Dropseed
Blepharoneuron tricholepis

- **Warm season**
- **Bunchgrass**
- **Native perennial**
- **2,500,000 seeds/lb.**
- **To 2' tall**

Identification

Leaf: 1 mm wide, 5 to 10 cm long; rolled, scabrous to hispidulous, tips obtuse. Flexuous.

Seedhead: Open panicle with ascending branches; pedicles flexuous; spikeiets about 3mm long. Flowering July to October.

Roots: Rhizomes absent.

Ligule: Membranous, truncate, entire, 0.5 to 2mm long.

Sheath: Open, scabrous. Folded vernation.

Collar: Glabrous.

Growing Conditions

Abundant in rocky, and moderately dry soils

- Adapted to a wide range of soil textures.
- Widespread on open slopes or in dry woods.
- Elevations 5,000 to 12,000 ft.

Reclamation Benefits

- Portability and quality of young plants is very good.
- Quality declines with maturity.

Notes

Sideoats Grama

Bouteloua curtipendula

- **Warm season**
- **Native perennial**
- **Adapted Varieties:**
  "Premier*
  "Vaughn"
- **Bunchgrass, Sod-former**
- **143,000 seeds/lb**
- **V to 2' tall**

Identification

Leaf: 2 to 7 mm wide, 5 to 30 cm long; flat with pustulate hairs present on margins near base of blade.

Seedhead: One sided panicle with 25 to 80 drooping branches. Purple tinge, bright orange anthers, short awns on the lemmas which fall away at maturity.

Roots: Short, scaly rhizomes.

Ligule: Membranous, erose, 0.2 to 0.6 mm long.

Sheath: Open, rounded and glabrous to pubescent, margins hyaline. Curled vernation.

Collar: Occasional pustulate hairs on margins, long.

Growing Conditions

- Does best on medium to course textured soils.
- Needs a well aerated soil.
- Adapted to all soil textures.
- Tolerates soil weakly to moderately saline.
- Tolerant to moderate drought.
- Establishes quickly.
- Can tolerate low fertility.
- Tolerates moderate grazing.

Reclamation Benefits

- Very palatable in spring and summer; only fair in the fall.
- Recommended for erosion control.
- Range and grassland use.
- Productive and palatable to livestock through out the year.

Notes

Black Grama
Bouteloua eriopoda

- **Warm season**
- **Native perennial, 12-24" tall**
- **Sod-former**
- **1,300,000 seeds/lb.**
- **Adapted Varieties:**
  "Nogal"
  "Sonora"

Identification

Leaf: 1 to 2 mm wide, 3 to 8 cm long. Flat, pustulate hairs on margins, internodes canescent, Widely spreading, wiry and slender tufted.

Seedhead: 4 or 5 loolely ascending spikes, 2 to 3 cm, long, spikelets 12 to 20, not crowded and pectinate, 7 to 10 mm long. Fertile lemma acuminate, with a terminal awn.

Roots: Roots at internodes of weak stems, forming a weak sod. Stoleniferous.

Ligule: Ciliate, 0.2 to 0.7 mm long.

Sheath: Open, rounded, pubscento to villous.

Collar: Continuous, Cured vernation.

Growing Conditions

- Widespread on dry hills and mesas.
- Found on shallow and calcareous sites.
- Adapted to sandy and silty soils.
- Excellent resistance to drought.
- Recommended in the 9" to 20" inch precipitation zone.

Reclamation Benefits

- Good portability and feeding value In summer and winter.
- Excellent for range seedings and stabilization of critical areas.
- A major grass of arid and semi-desert grasslands of New Mexico.

Notes

Blue Grama

Bouteloua gracilis

- **Warm season**
- **Native perennial**
- **Adapted Varieties:**
  "Hachita"
  "Lovington"
- **Bunchgrass, Sod-former**
- **712,000 seed/lb.**
- **6" to 24" tall**

Identification

Leaf: 1 to 2.5 mm wide, 2 to 15 cm long; flat.

Seedhead: 1 to 3 comb-like seedheads per stalk. May produce 2 or 3 crops of seedstalks in good years.

Roots: Shallow; long lived; spreads by tillering; short rhizomes.

Ligule: Dense, ciliate fringe, 0.2 to 0.7 mm long.

Sheath: Open, glabrous. Rolled vernation.

Collar: Yellow-green with occasional long hairs at edges.

Growing Conditions

- Grows best on clayey soils.
- Will tolerate moderate salinity, alkalinity and burning.
- Production is best in 12" to 14˚ precipitation zone.
- Very good drought tolerance; will become semi-dormant during severe drought.
- Growth and production occurs during warmest part of summer.

Reclamation Benefits

- Principle component of rangeland seed mixes.
- Important for elk use.
- High forage, nutrition, and palatability value, winter and summer.
- Resistant to heavy grazing; becomes sod-former under heavy grazing conditions.
- Suitable for erosion control.

Notes

Mountain Brome
Bromus marginatus

- **Cool season**
- **Native to Mountain areas**
- **1' to 4' tall**
- **Sod-former**
- **90,000 seeds/lb**
- **Adapted Varieties: "Bromar"**

Identification Characteristics

Leaf: 4 to 12 mm wide, 10 to 20 mm long; blades flat, pilose to pubscent. Stout, erect perennial.

Seedhead: Narrow, open panicle, hairy lemmas with a 1/4" terminal awn.

Roots: Fiberous, shallow roots.

Ligule: Membranous; obtuse; erose; 2 to 3.5 mm long.

Sheath: Closed to within a few centimeters of the ligule; pilose to pubescent.

Adaptive Characteristics

- Prefers deep, fertile and moist soils; medium to fine textures.
- Can survive on thin, course, dry soils at much reduced productivity.
- Tolerates saline conditions.
- 18" or greater annual precipitation zone.
- Cannot tolerate high water tables or flooding.
- Winter hardy.
- Short-lived pioneer species.

Reclamation Uses

- Erosion Control and Quick cover in Mountain areas
- Can be used in mixtures with Yellow sweetclover for short rotation pasture or green manure

Notes

Prairie Sandreed
Calamouilfa longifolia

- **Native**
- **273,000 seeds/lb.**
- **Warm season**
- **Sod-former**

Identification

Leaf: Flat below, involute above 10 to 60 cm long, 3 to 12 mm wide, basal portion keeled, glabrous, margins scabrous.

Seedhead: Panicle 15 to 40 cm long, narrow to spreading, shiny, branches ascending.

Ligule: Fringe of hairs ½ to 3 mm long.

Sheath: Round, glabrous to pubescent, pilose 2 to 3 mm long at the throat and collar.

Collar: Inflated.

Growing Conditions

- Grows rapidly in late spring and throughout the summer, remains green until frost, reproduces from seeds and rhizomes.
- Drought tolerant and may increase during dry years as associated grasses decline.
- Adapted to dry, moderately deep, infertile, sandy soils of very acid to slightly alkaline reaction (pH 4.5 to 8.0).
- Poor establishment from seed but good seed producer; reproduces well in the natural environment by vigorous rhizomes.
- Good summer growth but poor fall regrowth.
- Performs better if seeded In mixtures, use of this species on acid soils has not been evaluated.

Reclamation Benefits

- Lends diversity to mine soil plantings but better seeded to stabilize dry sand dunes or blow out areas not subjected to heavy grazing or trampling
- Palatable in spring an winter but does not withstand heavy grazing or trampling.

Notes

Orchardgrass
Dactylis glomerata

- **Introduced**
- **429,000 seeds/lb.**
- **Cool season**
- **Bunchgrass**

Identification

Leaf: Flat or folded 10 to 40 cm long, 2 to 11 mm wide, elongate prominent and scabrous mid-rib, margins scabrous.

Seedhead: Panicle 3 to 20 cm long; lower 2 to 3 branches elongate naked below, occasionally spreading; upper branches short, floriferous to the base, oppressed; spikelets clustered in dense 1-sided fascicles on each branch.

Ligule: Membranous, 2 to 8 mm long, erase to lacerate, obtuse.

Sheath: Keeled, laterally compressed, glabrous to slightly scabrous.

Growing Conditions

- Easy to establish from seed, good germination and seedling vigor.
- Long lived but lacks winter hardiness.
- Performs well In shade and on low fertility soils.
- Provides high quality forage; where moisture is available and temperatures are mild enough.

Reclamation Benefits

- Fast growing and good regrowth after grazing.
- Tolerant to close grazing.
- Better heat and drought tolerance than *Phleum pratense*.
- Unmatched for yield, quality, portability and regrowth.
- Provides excellent livestock hay or pasture.

Notes

Canada Wildgrass
Elymus canadensis

- **Cool season**
- **Bunchgrass**
- **Short-lived Perennial**
- **106,000 seeds/lb.**

Identification

Leaf: Green or often glaucous, culms erect, tufted to 1.5 m tall. Sheaths glabrous or pubescent; blades flat, scabrous or hispid on the upper surface, 1 to 2 cm wide.

Seedhead: Spike thick and bristly, nodding or drooping. Spikelets commonly in 3's or 4's, slightly spreading; awn about as long as the body; lemmas scabrous-hirsute, rarely glabrous, awn is curled when dry, 2 to 3 cm long.

Auricles: Large and clasping.

Ligule: Membranous, truncate, entire, ciliolate, 0.2 to 1.2 mm long.

Sheath: Open and rounded, glabrous to pilose.

Collar: Broad and glabrous. Rolled vernation.

Growing Conditions

- Well adapted to all soil textures, best on medium textures.
- Grows primarily on moist and sandy sites. Sometimes on disturbed sites.
- Moderate drought tolerant and winter hardy.
- Good soil salinity tolerance.
- Widespread in moist soils 4,000 to 8,000 ft.

Reclamation Benefits

- Fairly palatable during early growth stages for cattle and horses.
- Fair forage value for sheep and wildlife.
- Not competitive in mixtures, recommended for seeding in warm season mixtures for fall and spring pasture.
- A suitable species where rapid stabilization is needed.

Notes

Great Basin Wildrye
Elymus cinereus

- **Cool season**
- **Tall bunchgrass**
- **130,000 seeds/lb.**
- **Native**
- **Perennial**

Identification

Leaf: Blades flat, 4.5 to 15 mm wide, glabrous to densely harsh-puberulent.

Seedhead: Spike 10 to 25 cm long, thick and dense but not typically branched; glumes subulate, awn-pointed, lemmas glabrous to sparsely strigose, with a hyaline margin, awn-less or mucronate.

Auricles: Rudimentary.

Ligule: Membranous, obtuse, entire, 2 to 7 mm long.

Sheath: Open, glabrous to pubescent.

Collar: Glabrous. Rolled vernation.

Growing Conditions

- Well adapted to silty and clayey soils; somewhat tolerant to sandy loam textured soils.
- Good to very good tolerance to salt.
- Better adapted to winter-wet & summer-dry climates.
- Moisture concentrating site more controlling than precipitation zone.
- Very strong competitor, suppressing associates and herbaceous weeds.
- Robust, forming clumps 3 feet across, typically without, but often with short rhizomes.

Reclamation Benefits

- Extensive soil-binding, coarse, fibrous root system.
- Fair palatability to cattle, horses, and elk spring an fall.
- Useful for soil stabilization or drainages and disturbed soils.
- Excellent upland game bird cover and emergency winter big game forage.
- For use in moisture accumulating and high wildlife use areas.

Notes

Sand Lovegrass
Eragrostis trlchodes

- **Native**
- **Cool season**
- **50,000 seeds/lb.**
- **Sod-former**

Identification

Leaf: Flat or somewhat involute, 15 to 40 cm long, 2 to 8 mm wide, elongate, scabrous on upper surface, mid-rib prominent.

Seedhead: Panicle is 35 to 55 cm long, 7 to 30 cm wide, diffuse oblong to ovate, often purple or red, may be one-half the length of the plant, panicle branches in groups of 3 or 4, branches capillary, sparsely pilose in the axils.

Ligule: Ciliate membrane Vi to Vfe mm long.

Sheath: Round, imbricate, pilose at throat, occasionally hairy on the back or margins.

Growing Conditions

- Easy to establish from seed, good seedling vigor, produces an abundance of seeds.
- Performs well on all but the driest soils of the southern part of region.
- Short lived but readily reseeds itself.
- Leafy and remains green under drought conditions of midsummer.
- Does not possess adequate cold tolerance for widespread use.

Reclamation Benefits

- Good revegetation species for sandy, erosion prone soils, seeded for quick cover and forage production in range improvement programs.
- Performs well on all but the driest soils of the southern part of region.
- Remains green even under drought conditions of mid-summer; cures very well.

Notes

Arizona Fescue
Festuca arizonica

- **Coo1 season**
- **Bunchgrass**
- **Native perennial**
- **410,000 seeds/lb.**
- **Up to 3' tall**
- **Adapted Varieties:**
  " Redondo"

Identification

Leaf: Fine textured with barbs along edge. Obtuse tips, involute 10 to 30 cm long. Densely tufted giving a blue-green cast

Seedhead: On a tall slender culm. Alternate branching inflorescences

Roots: Dense; course; flberous. Turns dark purple when wet.

Ligule: Membranous, ciliolate, higher on the side to 2 mm.

Sheath: Open, overlapping. Folded vernation.

Collar: Inconspicuous.

Growing Conditions

- Prefers shallow loams, gravely or sandy sites.
- Adapted to loam to sandy loam soils during droughty part of the year.
- In association with Ponderosa pine in 14" precipitation zone.
- Very drought tolerant.
- Performs well on slightly acid mine waste when adequate precipitation is available.
- Moderately shade tolerant.
- Sets seed in July and matures by late summer.

Reclamation Benefits

- Stabilization of range land in inter-mountains.
- Very palatable to livestock and can be easily overgrazed.
- Good soil binding for erosio n control.
- Moderate use by el, mule deer and wild turkey.
- Moderately tolerant to grazing

Notes

Idaho Fescue

Festuca Idahoensis

- **Native**
- **Cool season**
- **1,050,000 seeds/lb.**
- **Tufted bunchgrass**

Identification

Leaf: Involute 5 to 25 cm long, filiform, firm, elongate, scabrous, often glaucous, glabrous abaxially, pubescent adaxially.

Seedhead: Panicle 7 to 15 cm long, narrow, dense, branches ascending, lower branches spreading.

Auricles: Small or absent.

Ligule: Ciliate membrane, less than 2 mm long, truncate.

Sheath: Flattened, keeled, glabrous or scabrous, green or glaucous basal sheaths short, open, wider than the blade.

Collar: Indistinct.

Growing Conditions

- Rather difficult to establish from seed, poor seed producer and weak seedling vigor but long lived once established.
- Moderate shade tolerance.
- Common in shrublands; grows well in sub-humid grasslands and semi-desert sagebrush grasslands.

Reclamation Benefits

- Good grazing tolerance but of only medium palatability, however it cures well on the stem for fall or winter forage

Notes

Sheep Fescue
Festuca ovna

- **Cool season**
- **Bunchgrass**
- **Perennial**
- **550,000 seeds/lb**
- **Adapted Varieties: "Covar"**

Identification

Leaf: Folded to involute, about 1 mm wide, 5 to 15 cm long. Tips obtuse or boat-shaped, with median lines down center of blades. Leaves in a dense basal tuft.

Seedhead: Panicle narrow, sometimes almost spikelike, 5 to 8 cm long, sometimes longer, spikelets 4 to 5 flowered; lemmas about 4 to 5 mm. long, Short owned.

Roots: Heavy, dense, fiberous system.

Ligule: Membranous, ciliolate, higher on the sides than in the center, about 0.4mm long.

Sheath: Open.

Collar: Narrow and indistinct. Folded vernation.

Growing Conditions

- Tolerant of shallow, gravelly, dry and exposed sites.
- Recommended for the 8" annual precipitation zone.
- Good drought tolerance.
- Poor salt tolerance.
- Good germination and growth rate; weak to moderate seedling vigor.

Reclamation Benefits

- Low to moderate palatability.
- Moderate grazing tolerance.
- Good soil builder due to its dense root system..
- Good in erosion control mixtures.

Notes

Galleta
Hilaria jamesii

- **Warm season**
- **Bunchgrass, Sod-former**
- **Native perennial**
- **159,000 seeds/lb.**
- **12" to 18" tall**
- **Adapted Varieties: "Viva"**

Identification

Leaf: 2 to 4 mm wide, up to 8 cm long; U-shaped, scabrous

Seedhead: Multiple seeds in clumps along stalk. Light purple in color before maturity, straw color at maturity.

Roots: Tough, woody rhizomes. Roots and rhizomes most abundant near surface, Reproduces by rhizomes and seeds.

Ligule: Membranous, obtuse to truncate, 1 to 1.5 mm long.

Sheath: Open, glabrous, margins glabrous.

Collar: Glabrous, margins sparsely villous.

Growing Conditions

- Adapted to all soil textures.
- Fair to good salt tolerance.
- Can survive with 3.7" per year precipitation.
- Grows primarily after sufficient summer rains.
- Very good drought tolerance.
- Low percentage of pure live seed (PLS), low seed production

Reclamation Benefits

- Palatable during summer growing season.
- Good erosion control.
- Withstands hearty grazing

Notes

Foxtail Barley
Hordeum jubatum

- **Cool season**
- **Native**
- **Tufted bunchgrass**
- **540,000 seeds/lb.**

Identification

Leaf: Decumbent at base; blades 2 to 5 mm wide, 5 to 10 cm long.

Seedhead: Culms erect, 30 to 60 cm tall; blades 2 to 5 mm wide, scabrous; spike nodding, 5 to 10 cm long, about as wide, soft, pale; lateral spikelets reduced to 1 to 3 spreading awns; glumes of perfect spikelet awnlike, 2.5 to 6 cm long spreading; lemma 6 to 8 mm long with an awn as long the glumes.

Ligule: Membranous 0.2 to 1 mm long, erose, truncate

Sheath: Round, glabrous to lightly pilose; auricles absent or small to ½ mm long.

Growing Conditions

- Tolerant of alkaline and saline sites.
- Adapted to a broad range of soil types.
- Found on open ground, meadows, waste places and where water accumulates.
- Troublesome weed, especially in irrigated meadows.

Reclamation Benefits

- Poor forage value for livestock and wildlife, may be lightly grazed before inflorescence development.
- Awns may cause sores in around the nose, eye, and mouth.
- Awns contaminate the fleece.

Notes

June Grass
Koeleria cristata

- **Warm season**
- **Bunchgrass**
- **Native perennial**
- **400,000 seeds/lb**
- **To 2' tall**

Identification

Leaf: 1 to 3 mm wide, 5 to 25 mm long; flat to involute puberulent, blade tips boat shaped or obtuse, median lines present.

Seedhead: Spike-like panicle, dense but often interupted at the base spikelets 5 mm long; glumes scaberulous, lemmas she than the glumes. Flowering May or early June.

Ligule: Membranous, obtuse to truncate, erose, ciliolate, to1.5 mm long.

Sheath: Open, hispid, rarely glabrous. Folded vernation.

Collar: Variable; folded vernation.

Growing Conditions

- Adapted to sandy and rocky soils.
- Adapted to dry, well drained soils, such as loams and sandy loams.
- Widespread on open slopes and meadows.
- Adapted to elevation from 6,000 to 11,000 ft.

Reclamation Benefits

- Moderately grazed by Mule deer spring and summer.
- Listed as a food Item for elk.
- Fair to good for forage for livestock
- Fair forage for antelope.
- Used by birds and small mammals for food and forage
- Greens up in early spring, subject to overgrazing.

Notes

Mountain Muhly
Muhlenbergia montana

- **Cool season**
- **Bunchgrass**
- **Native perennial**
- **1,500,000 seeds/lb.**
- **To 2' tall**

Identification

Leaf: 1 to 2 mm wide, 5 to 15 cm long; Blades flat to involute, scabrous, firm. Dense basal cluster, not branching.

Seedhead: Narrow panicle, Interupted, branches ascending or oppressed; spikelets 3-4 mm long, lower half of lemma pilose bearing flexuous aw n, 10-15 mm long. Flowering August to October.

Roots: Perennial with out rhizomes.

Ligule: Membranous, acute, entire, hyline, 4 to 10 mm long.

Sheath: Open, longer than the internodes, scaberulous; folded vernation.

Growing Conditions

- Wide variety of soil types.
- Adapted to open, rocky slopes.
- Widespread; elevations from 7,500 to 11,000 ft.
- Recommended for the 15" to 19" precipitation zone.

Reclamation Benefits

- Excellent forage for deer and elk through out the year.
- Withstands moderate grazing.
- Used for soil stabilization.
- 5 to 10% of diet for Wild turkey during fall and winter.

Notes

Spike Muhly

Muhlenbergia wrightil

- **Warm season**
- **Bunchgrass**
- **Native perennial**
- **181,000 seeds/lb.**
- **Up to 40" tall under good conditions**
- **Adapted Varieties:**
  "El Vado"

Identification

Leaf: 1 to 4 mm wide, 6 to 15 cm long; flat to folded, scabrous above, glabrous beneath. Light green, smooth and wiry, Closely tufted.

Seedhead: Narrow, grey-black, similar appearance to Wild timothy.

Roots: Short rootstock; in bunches up to 2' diameter.

Ligule: Membranous, truncate, ciliolate 1 to 5 mm long.

Sheath: Open, compressed-keeled, shorter than internodes.

Growing Conditions

- Prefers fine to medium textured soils.
- Wide variety of soil types, in association with the Pinon-Juniper community.
- Recommended for the 15" to 19" precipitation zone.
- Slow to develop, establishes In 3 years.
- Stems remain green into winter.

Reclamation Benefits

- Most palatable of species; valuable to all classes of livestock.
- Excellent forage for deer and elk through out the year.
- Soil stabilization.
- Withstands moderate grazing.
- 5 to 10% of diet for Wild turkey during fall and winter.

Notes

Indian Ricegrass
Oryzopsis hymenoides

- **Cool season**
- **Bunchgrass**
- **Native perennial**
- **183,000 seeds/lb.**
- **1' to 2' tall**
- **Adapted Varieties: "Paloma"**

Identification Characteristics

Leaf: 1-2 mm wide, 10 to 30 cm long; Involute and scabrous .Many tightly rolled, slender leaves.

Seedhead: Widely spreading, with a single flower at the end of each branch. Seeds are black, round and covered at one end with short white hair.

Roots: Very drought tolerant.

Ligule: Membranous, acute, lacerate, 2.5 to 7.5 mm long.

Sheath: Open with ciliate margin, glabrous to pubescent, often buried in sand.

Collar: Inconspicuous. Occasionally villous on margins.

Adaptive Characteristics

- Grows best on sandy and silty textured soils.
- Characteristic of infertile, dry, sandy soils.
- Fair tolerance to saline conditions.
- Poor high water tolerance.
- Recommended for the 10"-18" precipitation zone, but can survive on 5"-7" per year.
- Very good drought tolerance.
- Difficult to establish, may contain many hard seed.
- Short lived: 3 to 4 years, reproduces by seed primarily.

Reclamation Uses

1. Standing winter feed, good portability and nutritious.
2. Moderately tolerant to close grazing.
3. Excellent elk, deer and antelope feed.
4. Seeds and forage important to birds and big game.
5. Good erosion control on sandy sites.

Notes

Switchgrass
Panclum virgatum

- Native
- Warm season
- 389,000 seeds/lb
- Sod-former

Identification

Leaf: Flat 10 to 60 cm long, 3 to 15 mm wide, elongate, firm, triangular patch of hair adaxlally at the base, margins weakly scabrous.

Seedhead: Panicle 15 to 55 cm long, diffuse, spikelets toward ends of long branches; lower branches in whorls, pairs, or single.

Ligule: Ciliate membrane Vh to 3V2 mm long, mostly hairs, obtuse.

Sheath: Round, glabrous to dilate at margins, often purplish to reddish at base.

Collar: Ciliate

Growing Conditions

- Relatively easy to establish from seed, good seedling vigor, long lived.
- Very little tolerance to shade.
- Requires more moisture during the growing season than is usually available on the Great Plains.
- Found on wet prairies in marshes or along riverbanks and most abundant in relatively moist, fertile areas.

Reclamation Benefits

- Tolerant of moderate grazing and acid soils.
- Valuable wildlife cover and source of wild bird feed.
- Some use as hay.

Notes

Reed Canary Grass
Phalaris arundinacea

- **Cool season**
- **Sod-former**
- **Tall perennial**
- **540,000 seeds/lb**.

Identification

Leaf: Flat, scabrous, 6 to 15 mm wide, 10 to 30 cm long.

Seedhead: Culms erect, 60 to 150 cm tall, panicles 7 to 18 cm long, narrow with branches spreading during anthesis, the lower branch as much as 5 cm long; glumes about 5 mm long, narrow, acute; keel scabrous, vary narrowly winged; fertile lemma, lancelolate, 4 mm long, with few oppressed hairs.

Roots: Develops from glaucous, creeping rhizomes.

Ligule: Membranous, acute, occasionally lacerate, 3 to 8 mm long.

Sheath: Open and rounded with overlapping margins.

Collar: Narrow and oblique. Rolled vernation.

Growing Conditions

- Well adapted to poorly drained soils.
- Limited to areas that are wet or receive additional moisture.
- Fair drought tolerance.
- Does not tolerate sodic soil conditions
- Moderate seedling vigor; slow growth rate.
- Tolerates acid soils.
- Can be seeded, sprigged or planted by culm cuttings.

Reclamation Benefits

- Used for forage and erosion control in wet areas.
- Intolerant to close grazing.
- Used by birds for cover and food source.

Notes

Kentucky Bluegrass
Poa pratensis

- **Cool season**
- **Sod-former**
- **Introduced Perennial**
- **2,150,000 seeds/lb.**
- **8" to 31" tall**

Identification Characteristics

Leaf: 2 to 4 mm wide, 5 to 20 cm long; blade flat or folded, boat shaped tip. Median lines present.

Seedhead: Open panicle, pyramidal or ovoid lemmas silky-pubescent below the middle on the keel and marginal nerves. Flowering June to August,

Roots: Rhizomatous, sod-forming,

Ligule: Membranous, truncate, 1 to 2 mm long, shorter than wide,

Sheath: Smooth to scaberulous, closed about 1/2 the length.

Adaptive Characteristics

- Adapted to a broad range of soils.
- Spreads by rhizomes.
- Becomes dormant if moisture is limiting.
- Recommended for the 12" to 18" precipitation zone in mountain areas.
- Most common on sites with ample soil moisture.
- Widespread in open meadows, woods and roadsides,
- Found at elevations from 4,000 to 10,000 ft.

Reclamation Uses

- Riparian areas.
- Forage for cattle and wildlife in early spring,
- Common in fields and meadows.

Notes

Sandberg Bluegrass

Poa sandbergii
Poa secunda

- **Cool season**
- **Bunchgrass**
- **Native perennial**
- **925,000 seeds/lb.**
- **8" to 16" tall**

Identification

Leaf: 1 to 3 mm wide, 3 to 8 cm long. Short and basal, boat-shaped tips, turn brown once it headsout. Flat to V-shaped. Median lines present. Forms small dense tufts 2" to 12" In diameter.

Seedhead: Contracted panicle with a purplish tinge, 1" to 4" long.

Roots: Shallow to deep, fiberous and finely branched.

Llgule: Membranous, acute, 2.5 mm long.

Sheath: Overlapping margins, occasionally purplish at base; folded vernation.

Growing Conditions

- Adapted to most soils. Including dry. rocky soils.
- Tolerant to weakly alkaline, acid or saline soil conditions.
- Good drought tolerance.
- Not tolerant to prolonged flooding.
- Winter hardy.
- Nearly disappears during hot summer months.
- Matures early.

Reclamation Benefits

- Grazing/Rangeland use.
- Good portability for all livestock and wildlife in early spring.
- Short lived, provides early cover and adds to diversity.

Notes

Bluebunch Wheatgrass
Pseudoroegneria spicata

- **Native perennial**
- **Cool season**
- **88,000 seeds/lb.**
- **Sod-former**

Identification

Leaf: Loosely involute to flat, 5 to 25 cm long, 1 to 5 mm wide, elongate, pubescent adaxially, margins white and weakly barbed.

Seedhead: Spike, 8 to 15 cm long, slender, 1 spikelet per node, usually only 5 to 14 spikelets, spikelets not imbricate to one-eighth imbricate, rachis internodes 1 to 2 cm long.

Ligule: Erose to ciliate membrane ½ to 2 mm long, rounded or truncate.

Sheath: Round, glabrous to appressed-puberulent, margins imbricate, open; auricles well-developed ½ to 1 mm long, acute, clasping, reddish; old sheaths strongly persisting.

Collar: Ciliate

Growing Conditions

- Poor to moderate salinity tolerance.
- Good drought tolerance
- Adapted to most textures, best on well drained soils.
- Adapted to the 10" to 20" precipitation zone.
- Fair seeding vigor; good seed producer and fair ease of establishment form seed.

Reclamation Benefits

- Growth begins in April, and the plants stay green well into the summer; regrowth occurs following fall rains.
- Excellent for cattle and horses; food for sheep, elk, and deer.
- Cures well and makes good standing winter feed.
- Valuable stabilizer on dry slopes where palatabllity Is desirable.

Notes

Alkali Sacaton
Sporobolus airoides

- **Warm season**
- **Native perennial**
- **Bunchgrass**
- **1, 750,000 seeds/lb**
- **2' to 2.5' tall**
- **Adapted Varieties:**
  "Salado"
  "Saltalk"

Identification

Leaf: 2 to 4 mm wide, 30 to 40 mm long; flat at base and Involute towards tips.
Seedhead: Widely spreading panicle, 1/2 height of plant.
Roots: Deep and coarse, 8" to 12" clump diameter at ground level. Devoid of rhizomes.
Ligule: Very short, ciliate fringe.
Sheath: Open, glabrous; curled or clasping vernation.

Growing Conditions

- Found on clayey sites along with Western wheatgrass and Four-wing saltbush,
- Tolerant of sodic, saline, saline-sodic soils.
- Found where saline soil conditions exist.
- Soil pH: 6.5-8.6, for best growth.
- Recommended in the 6" to 10" precipitation zone.
- Good drought tolerance.
- Withstands poor draining of flooding soils.
- Well adapted for soil erosion control.

Reclamation Benefits

1. Grazing/Rangeland use.
2. Fair to good forage production during period of rapid growth.
3. Poor forage when dry.
4. Limited grazing for deer and antelope when green.
5. Seeds are eaten by Sparrows and various game birds.
6. Can withstand heavy grazing.

Notes

Sand Dropseed
Sporobolus cryptandrus

- **Warm season**
- **Bunchgrass**
- **Native perennial**
- **5,000,000 seeds/lb.**
- **1' to 3.5' tall**

Identification

Leaf: 2 to 5 mm wide, 5 to 15 mm long. Flat, involute at tip; short & wide leaves. Rough surface. Outer stems spread nearly horizontally.

Seedhead: Pyramidal, 3- to 14" long; base may be enclosed In sheath. Good seed producer.

Roots: Shallow, good for erosion control.

Ligule: Dilate, about 0.5mm long.

Sheath: Open, one margin ciliolate, strongly overlapping.

Collar: Broad and pilose at the margins; rolled vernation.

Growing Conditions

- Invader or early successional type on sandy soils.
- Fair tolerance to saline conditions.
- Recommended for the 8" to 10" precipitation zone.
- Very drought tolerant.
- Valuable grass for ease of establishment.
- Will withstand heavy grazing.

Reclamation Benefits

- Readily grazed prior to maturity.
- Fair winter forage.
- Good revegetation grass.
- Erosion and sandy site stablization.

Notes

Needle and Thread
Stipa comata

- **Cool season**
- **Bunchgrass**
- **Native perennial**
- **115,000 seeds/lb**
- **1.5' to 2.5' tall**

.

Identification

Leaf: 1 to 3 mm wide, 5 to 25 cm long; involute, scabrous on upper surface, last inch of leaf withered and dry.

Seedhead: l'-4' tall, erect, smooth culm, inflorescence is contracted and partially in the sheath. 4" to 5" long twisted awn attached to lemma.

Roots: Deep, moderate ease of establishment.

Ligule: Membranous, acute, lacerate, 1 to 5 mm long.

Sheath: Open, margins overlapping, strongly ribbed. Folded vernation.

Collar: Continous and glabrous.

Growing Conditions

- Best on sandy and medium textured soils.
- Found on shallow, rocky and silty sites.
- Fair tolerance to saline conditions.
- Not tolerant to very acid or very alkaline soils.
- Recommended in the 10" to 18'precipitation zone.
- Can grow with less than 10" and up to 20" annual precipitation.
- Good drought tolerance.

Reclamation Benefits

- Rangeland/Grazing use.
- Moderately tolerant to close grazing.
- Sharp awns may cause irritation to domestic livestock.

Notes

Green Needlegrass
Stipa viridula

- **Cool season**
- **Native perennial**
- **Bunchgrass**
- **181,000seeds/lb.**
- **To 18" tall**
- **Adapted Varieties**
  "Green stipagrass"
  "Lodorm"

Identification

Leaf: 2 to 5 mm wide, 10 to 25 mm long; blades flat to rolled. Tufted form.

Seedhead: Panicle branched-appressed; glumes 7-10 mm long; lemma 5-6 mm long, oppressed-pubescent, awn twice-gemiculate. Flowering July and August.

Roots: Deep.

Ligule: Membranous, to 1 mm long.

Sheath: Open, one margin ciliate.

Collar: Narrow, pilose at the margins, hispidulous to pilose in a line across collar; rolled vernation.

Growing Conditions

- Adapted to medium to clayey textured soils.
- Fair tolerance to saline conditions.
- Recommeded for the 12" to 18" precipitation zone.
- Fair to good drought tolerance.
- Good growth rate, excellent seedling vigor.
- Starts growth relatively early and remains green until late in season.

Reclamation Benefits

- High forage quality, with good forage yield.
- Reduced palatability when mature.
- Moderately tolerant to grazing.
- High value to songbirds and small rodents.

Notes

Woolly Yarrow
Achlllea lanulosa

- **Warm season**
- **Native**
- **2,770,000 seed/lb.**
- **10" to 24" tall**

Identification

Leaf: 5 to 10 cm long, linear to narrowly oblong In outline, finely bipinnatifid, hairy, Feathery fern-like. Fibrous stem.

Flower: Head is a dense, short-peduncled corymbs. 4-5 mm high bracts about 20 mm, 2 to 6 rays, 3-4 mm long, roundish yellowish to brown.

Roots: Rhizomous, creeping rootstock.

Growing Conditions

- Adapted to a wide range of soils.
- Grows in dry, open sites and common in pine forests.
- Found at elevations from 5,000 to 10,000 feet.
- Good adaptation to roadsides and disturbed sites.

Reclamation Benefits

- Fair forage for sheep, lesser value for cattle.
- Lightly grazed by Mule deer.

Notes

Fringed Sagebrush
Artemisia frigida

- **Native perennial herb**
- **To 15" tall**
- **4,536,000 seeds/lb.**

Identification

Leaf: Silky-canescent, twice-pinnatifid, linear segments; perennial herb, often woody at the base, stems to 40 cr tall, simple or branching.

Flower: Many flower heads, racemose-paniculate, marginal flowers pistillate and fertile, inner flowers perfect and fertilile; recepticle with long hairs. Flowers July to October.

Roots: Deep and spreading.

Growing Conditions

- Best on medium to clayey textured soils of the dry plains and hills.
- Adapted to highly saline or acidic soil.
- Recommended for the 8" to 10" precipitation zone.
- Seed with grasses on arid lands to prevent erosion.
- Northern and Central New Mexico; 5,500 to 8,000 ft.
- Wide range of adaption.

Reclamation Benefits

- Good portability
- Important to many small and big game species.

Notes

Prairie Sagebrush
Artemisia ludvoiciana

- **Native perennial herb**
- **4,500,000 seeds/lb.**
- **To 1 meter tall**

Identification

Leaf: Linear to lanceolate, oblong, or oblanceolate. 3 to 10 cr long, entire or toothed or lobed. Sometimes glabrate c upper surface.

Flower: Numerous heads, erect or nodding, compact panicl< receptacle glabrous, 12 flowers per head. Marginal flowe pistillate and fertile; inner flowers perfect and fertile. Flowers July to September.

Roots: Deep and spreading.

Growing Conditions

- Adapted to highly saline or acid soils.
- Recommended for the 8" to 10" precipitation zone.
- Seed with grasses on arid lands to prevent erosion.
- Prairies, canyons, and mountain slopes; 4,000 to 8,000 ft.
- Wide range of adaption.

Reclamation Benefits

- Good portability.
- Important to many small and big game species.
- Used as cover and food source for small animals.

Notes

Pacific Aster

Aster adscendens
A.chilensis ssp. adscendens

- **Native perennial**
- **500,000 seeds/lb.**
- **9" to 2' tall**

Identification

Leaf: Entire, glabrous to pubescent, margins scabrous to about 10 cm long, basal leaves spatulate to oblancelolate, short petiolated, cauline leaves linear-lanceolate to oblor sessile.

Flower: Heads about 2.5 cm in diameter; the involucre 4 to 7 mm high, with green-tipped bracts that are either blunt at the tip or abruptly short-pointed. 15 to 40 rays are blue, violet or pink, 10 to 15 mm long.

Fruit: Pubescent.

Stem: Perennial lacking woody base, rigid and slender, 20 to 60 cm tall and more or less hairy, especially above.

Growing Conditions

- A common, highly variable species partial to mountain meadows and openings.
- Occurs on plains, hills and moist banks.
- Generally found between 6,500 and 8,000 feet in meadows, moist grasslands and open woodlands in New Mexico.
- Flowers from July to September.

Reclamation Benefits

- Palatability varies greatly with species.
- Appears to be often fair feed for both sheep and cattle.
- Said to be a selenium-absorber to an extent to make it poisonous to stock, but not confirmed.
- Recommended for use in grass mixtures for stabilizing critical areas near ponds, spillways, road cuts and fills.
- Erosion control in stream overflow areas.

Notes

Aster

Aster spo.

- **Perennial herb**
- **750,000 seed/lb.**
- **9" to 24" tall**

Identification

Leaf: Alternate, entire or toothed to 10 cm long, short petioled. Lanceolate to oblong-ovate.

Flower: Corymb or panicles. Disk flower are yellow and the ray flowers are violet to purple and rarely white. Flowers July to September.

Roots: Rhizomes or fiberous systems.

Growing Conditions

- Adapted to most soil types; establishes easily on disturbed sites.
- Many species found along streams, roadsides or wet areas
- Excellent tolerance to drought.
- Mountain medows; 6,500 to 8,000 Feet.
- 60 species in the Western United States.
- Selenium absorber to an extent to be poisonous to stock.

Reclamation Benefits

- Not a significant part of livestock forage.
- Negligible Importance as livestock feed.
- Often some varieties of aster are foraged by sheep and cattle.

Notes

Cicer Milkvetch
Astragalus cicer

- **Nitrogen-fixer**
- **145,000 seeds per lb.**
- **Introduced from Sweden**

Identification

Leaf: 4-8' long, odd-pinate, with 21-27 light green leaflets, about 1-2" long. Sparsely hairy.

Flower: A contracted raceme with 15-60 pea-like pale yellow to white flowers which mature into inflated, bladder-shaped leathery, hairy reddish-green to green pods, turning black at maturity.

Fruit: Pods contain numerous seeds that detach and inside. Seeds are bright yellow to pale green, flattened and egg-shaped.

Growing Conditions

- Well adapted to all soil textures, best on loams and sandy loams.
- Recommended for optimum performance in 18" to 20"+ precipitation zone.
- Generally grown between 2,000 and 8,000 feet in meadows, moist grasslands and open woodlands.
- Good performance in association with shrubs.
- May form nearly total cover from underground rhizomes and foliar spread under favorable conditions.

Reclamation Benefits

- Palatable to livestock, elk, deer and antelope.
- Non-bloating and non-toxic.
- Well rated potential for use in restoring big game range in intermountain West.
- Recommended for use in grass mixtures for stabilizing critical areas near ponds, spillways, roadcuts and fills.
- Erosion control in stream overflow areas.

Notes

Winged Wild Buckwheat
Erogonum alatum

- **Perennial herb**
- **250,000 seeds/lb.**
- **8" to 30" tall**

Identification Characteristics

Leaf: Basal, 3 to 10 cm long spatulate to narrowly oblanceolate. Stems erect, from thick taproot, simple branched, 20 cm tall.

Flower: Elongate open panicle, branches usually pubescent. Brats leaflike, involucres 2.5 to 3.5 mm long. Peduncled.

Roots: Thick taproot with woody base.

Growing Conditions

- Widespread from dry sagebrush plains to open conifero woodland.
- Tolerant to drought
- Adapted to saline conditions
- Adapted to clayey bottom soils

Reclamation Benefits

- Used by small animals.

Notes

Rocky Mountain Iris
Iris missouriensis

- **Native perennial**
- **27,900 seeds/lb.**
- **8' to 20" tall**

Identification

Leaf: 8" to 20" long, 1/4" to 1/2" wide; flexible, tough, sword shaped.

Flower: 3" to 4" wide, 3 sepals, resembling petals, curved downward 3 petals, erect. Large delicate pale blue or blue-violet. Blooms at the top of leafless stalk.

Roots: Spreads by tubers.

Growing Conditions

- Found in medows and streambanks.
- Always where moisture is abundant untill flowering time.
- Forms large dense patches In low spots in pastures.

Reclamation Benefits

- Tough leaves are avoided by cattle.
- Adds diversity.

Notes

Blue Flax
Linum lewisii

- **Perennial herb**
- **293,000 seeds/lb.**
- **Up to 2.5' tall**

Identification

Leaf: Crowded along stem, linear 10 to 30 mm long. Ascending, alternate and simple. Stems 20 to 50 cm tall, branching several in a cluster, older stems striate.

Flower: Axillary, terminal one sided racemes; petals blue, rarely white, 10 to 15 mm long, 5 sepals each with 5 petals separate. Flowering June to August.

Roots: Fibrous

Growing Conditions

- Naturally found on well drained sands to rocky soils.
- Fair to poor tolerance of saline conditions.
- Good drought tolerance.
- Open meadows, widespread; 4,500 to 11,550 ft.
- Germination in 3-4 weeks at 54 degrees F.

Reclamation Benefits

- Portability rated as low.
- Adds diversity to seed mix.
- Good for slope stability.

Notes

Alfalfa: Rhizoma

Medicago sativa

- **Perennial**
- **Introduced (Europe)**
- **Nitrogen-fixer**
- **210,000 seeds/lb.**
- **Adapted Varieties: "Ranger"**

Identification

Leaf: Leaflets 10 to 30 mm long, oblong to obovate; stem erect to ascending, branched to 1 meter tall, sparsely hairy.

Flowers: Racemes dense, 1 to 5 cm long; corolla violet, 7 to 9 mm long. Flowers from May to October.

Roots: Nitrogen-fixing perennial. Spreads by rhizomes.

Growing Conditions

- Adapted to all soil textures.
- Requires good drainage.
- Tolerant to weakly acid soils.
- Recommended for the 15" precipitation zone.
- Fair drought tolerance.
- Easily established, good germination.
- Strong taproot with vigorous growth habit.

Reclamation Benefits

- For use in range, pasture and revegetation mixes.
- Soil improvement, erosion and nitrogen-fixing.
- Wildlife plantings.

Notes

Yellow Sweetclover
Melilotus otticinalis

- **Biennial**
- **Introduced (Europe)**
- **Nitrogen-fixer**
- **260,000 seeds/lb.**
- **Mid to tall**

Identification

Leaf: Stems to 2 meters tall, branched, sparsely pubescent. Leaflets 10 to 30 mm long, oblong to oval rounded at the apex. Sharply serrate, glabrous.

Flower: Secund, in racemes, 2 to 12 cm long, calyx lobes shorter than the tube; petals yellow 5 to 6 mm long. Flowers May to October.

Roots: Nitrogen fixing biennial.

Growing Conditions

- Adapted to all soil textures.
- Fair to good saline tolerance.
- Recommended for the 12" precipitation zone.
- Good drought tolerance.
- May retard growth of warm season species because of water competition,
- Known to accumulate molybdenum.

Reclamation Benefits

- Forage for small and large animals.

Notes

Hookers Evening Primrose
Oenothera hookerill

- **Native forb**
- **Large yellow flowers**
- **Biennial**

Identification

Leaf: 6"-12" long, lanceolate, numerous progressively larger from top to base of stem.

Flower: 2"-3" wide; sepals 4, reddish; petals 4 broad and yellow becoming rather orange as they age the following day, broadly obovate; stamens. Flowering from June to September.

Fruit: Slender-rigid, pod1"-2" long. Obtusely angled, seeds rows in each cell, sharply angled.

Stalk: Tall, erect, 2'-3', usually unbranched stem with large yellow flowers in a raceme.

Growing Conditions

- 6,000 to 9,000 feet in elevation on open slopes and valleys.
- Drought tolerant.
- Found in the 8" to 12" precipitation zone.

Reclamation Benefits

- Grazed by White-tail and Mule Deer.

Notes

Rocky Mountain Penstemon

Penstemon strictus

- **Cool season**
- **Native perennial**
- **592,000 seeds/lb.**
- **8' to 23" tall**
- **Adapted Varieties: "Bandera"**

Identification

Leaf: Dark green, shiny, opposite, entire, long and often curled. Stems arise from a basal rosette. Spreading to upright

Flower: Solitary, on one side of raceme, showy blue to purple. Tube of flower often lighter. Flowering does not occur during first years growth.

Roots: A few large and many fine roots. Shallow, fibrous, from 6" to 10" depth. Stems are known to layer.

Growing Conditions

- Does well on rocky, sandy or loamy soils.
- Adapted to thin soils.
- Tolerates weakly alkaline to weakly acid soils.
- Does best in the 15" to 20" precipitation zone.
- Only moderately drought tolerant.

Reclamation Benefits

- Portability to cattle and sheep is fair to poor.
- Good to excellent forage for deer, elk, and antelope because of early spring growth.

Notes

Purple Prairie Clover

Petalostemum purpureum

- **Perennial**
- **Legume:nitrogen-fixer**
- **300,000 seeds/lb.**
- **1' to 3' tall**

Identification

Leaf: 3 to 5 foliate, leaflets linear 8 to 20 mm long, mostly folded, leaflets dotted with resinous glands on undersurface. Stems are erect, striate, vilious to glabrous.

Flower. Spikes 1 to 5 cm long, dense, cylindric, rose to purple colored corolla. 1 or 2 seeded with only 5 stamens. Flowering from July to September.

Roots: Legume, nodules with nitrogen-fixing mycorrhizae. Deeply rooted.

Growing Condition

- Prefers deep, well drained soils.
- Recommended for the 16" or greater annual precipitation zone.
- Generally found in open prairies and foothills.
- Rapid growth rate.
- Self sows readily.

Reclamation Benefits

- Grazed by sheep, to scarce to be of importance as forage ir most parts of range.
- Provides nutritious, high-protein forage when available.
- Lightly browsed by Mule deer.

Notes

Mexican Hat
(Prairie Cornflower)
Ratibida columnifera

- **Perennial flower**
- **1,230,000 seeds/lb.**
- **Up to 30" tall**

Identification

Leaf: Pinnately parted into 5 or more segments, linear to oblong. Stems bristly, erect and branch to 80cm tall.

Flower: Heads 15 to 40 mm long, disc cylindrocolumanr; bracts 5 to 12 mm long, linear; rays 20 to 40 mm long, yellow. Flowers June to September.

Growing Condition

- Adapted to calcareous soils.
- Fair tolerance to saline conditions.
- Good drought tolerance. Found on plain and open slopes.
- Widespread; 5,000 to 7,000 feet.
- Rapid to moderate growth rate.
- Prefers cool temperatures to germinate.
- 60% PLS is average.

Reclamation Benefits

- Low maintenance component of a mixed meadow planting.
- Listed as food item for Mule deer.

Notes

Scarlet Globemallow
Sphaeralcea coccinea

- **Warm season**
- **Native perennial**
- **500,000 seeds/lb.**
- **4" to 12" tall**

Identification

Leaf: Alternate, deeply cleft with palmate divisions, covered with pubescence. Branches wided at tip.

Flower: Short stalked, at first crowded into dense terminal clusters and later elongating. Copper-scarlet to salmon colored petals 10 to 20 mm long.

Roots: Rhizomatous.

Growing Conditions

- Adapted to dry soils.
- One of the most drought resistant forbs.
- Looses its leaves during driest periods.
- Performs well in the Pinon-Juniper, Sagebrush, Shadscale and Greasewood communities.
- Can become an increaser species in overgrazed areas or during a drought.

Reclamation Benefits

- Erosion control and early succession on reclaimed areas.
- Excellent forage for deer
- Little value as forage for livestock.

Notes

Utah Serviceberry
Amelanchier utahensis

- **Native shrub**
- **45,000 seeds/lb.**
- **Shrub or small tree**

Identification

Leaf: Elliptic to ovote or obovate, rounded to truncate at the base, rounded-acute at apex, 6 to 35 mm long; glabrous to puberulent upper and lower surfaces. Finely crenate to crenate-serrate.

Flower: 3 to 6 flowered raceme, pedicles and raceme pubescent; sepals acuminate, pubescent becoming glabrous, orange or yellow, globose or ovoid. Flowering April and May.

Roots: Good germination and persistence.

Growing Conditions

- Dry rocky slopes to deep moist soils; best on medium to clayey textured soils.
- Poor tolerance to saline conditions.
- Only fair drought tolerance.
- Fair ease of establishment.
- Plant by broadcast seeding method.
- Moderate growth rate.

Reclamation Benefits

- Tolerant to grazing.
- At maturity it can produce large amount of forage in low rainfall years.
- High quality wildlife forage; preferred winter forage for big game animals.
- Good erosion control.

Notes

Four-Wing Saltbush
Atriplex canescens

- **Native perennial shrub**
- **70,000 seeds/lb.**
- **3' to 6' tall**

Identification

Leaf: 10 to 50 mm long, usually sensile, linear-oblong, obtuse at apex. Entire margin, greyish-scurfy. Stems branching, scurfy.

Flower: Fruiting bracts united at apex, four-winged from back or sides; flowers in small glomerules arranged terminally in panicles of spikes. Dioecious.

Roots: Nitrogen-fixing endotrophic mycorrhizae may occur on roots.

Growing Conditions

- Adapted to all soils; best on calcareous soils.
- Very tolerant to saline and alkaline conditions.
- Recommended for the 8" to 15" precipitation zone.
- Good drought tolerance.
- Adequate soil moisture greatly increases rate of establishment.
- Survives and grows in broad environmental conditions.
- Good soil stabilization.

Reclamation Benefits

- Browsed by wildlife and livestock all seasons.
- Thick stands good for erosion control.
- Highly palatable and nutritious.
- Low tolerance to close grazing.

Notes

Shadscale
Atiplex confertifolla

- **Native perennial shrub**
- **15,000 seeds/lb.**
- **1/2'to 3'tall**

Identification

Leaf: Crowded, deciduous, variable shape orbicular to ovate, obovate or elliptic, loose rounded or cuneate, apex obtuse, margins entire 3/8" to 3/4", firm, greyish-green scurfy surface, short petiole.

Flower: Dioecious, staminate spikes with leafy bracts.

Roots: Nitrogen fixing endotrophic mycorrhizae may occur on roots.

Growing Conditions

- Tolerant of stony alkaline soils.
- Dominant in eroded desert areas.
- Recommended for the 8" to 15" precipitation zone.
- Good drought tolerance.
- Survives and grows in broad environmental conditions.
- Good soil stabilization.

Reclamation Benefits

- Good winter sheep browse.
- Less so for cattle because of spines.
- Browsed by Mule deer.
- Resistant to overgrazing.
- Seeds are eaten by at least six bird species.

Notes

Mat Saltbush
Atriplex corrugata

- **Native shrub**
- **35,000 seeds/lb.**
- **Forms dense, matlike mounds to 18" tall**

.Identification

Leaf: Crowded, opposite or alternate, linear to oblong, or linear-spatulate, l/4"-l" long. Apex obtuse to rounded, base cuneate or gradually narrowed, margin entire or denticulate.

Flower: Dioecious, occasionally monoecious, Inflorescence mostly erect and slender being borne from stem. Staminate spikes with sesile, nearly naked glomerules, perianth 5-cleft, stamen as many as the perianth segments; pistillate in elongate terminal spikes, pistil with two oppressed bracts.

Fruit: Reddish brown, 1/4" long, 1/2" wide, surfaces flattened, thick tubercled or appendaged dorsally, apical margins entire or denticulate.

Stem: 4"-12" high, decumbent or errect, closely branched densely furfuraceous, woody at base.

Growing Conditions

- Tolerant of saline or alkine soil in the plains.
- Recommended ofr the 8" to 15" precipitation zone.
- Good drought tolerance.
- Grows at altitudes of 4,000 to 6,500 feet.

Reclamation Benefits

- Beneficial for sodic/saline reclamation.
- Browsed by sheep.
- Soil stabilization

Notes

Nuttall Saltbush
Atriplex nuttallii

- **Native shrub**
- **Small half-shrub**
- **114,000 seeds/lb.**
- **½' to 2' tall**

Identification

Leaf: Alternate, sometimes opposite on lower leaves, blade 2 to 5 cm. long, 5 to 10 mm wide, oblong-linear to obovate, base narrowed or cuneate, apex obtuse or rounded, margin entire, thick and firm. Surfaces gray-green to green with a dense mealy scurf.

Flowers: Dioceious or rarely monoecious; staminate in terminal glomerate spikes which are leafy below; Flowers May through July.

Fruit: Bracts sessile or short stalked, 1.5 to 6.5 mm long, thickened, generally ovate to rounded, terminating in a lanceolate or cuneate-oblong beak, more or less toothed at summit; seed 1 to 2 mm long, radicle superior. Fruits mature from August to November.

Stems: Twigs slender, herbaceous above, woody below, scurfy grayish green or whitened at first, later glabrous to dark brown or gray and roughened below.

Roots: Shallow to moderately deep, well branched. Some plants root sprout and layer.

Growing Conditions

- Adapted to medium to fine textured soils; tolerant to all but erosive sands or deep clays.
- Common in moderate to strong saline soils.
- Adapted to 5"+ annual precipitation zone, does best In 8" to 12" zone.
- Found on dry hills and slopes; 5000 to 7,000 feet.
- Slow growth and establishment rate.

Reclamation Benefits

- Good palatability for livestock and deer In winter, fair for antelope.
- On mined lands, seed sperate from grass species for better stands.
- Good on harsh saline sites where few other species are adapted.

Notes

Broadscale
Atriplex obovata

- **Native subshrub**
- **15,000 seeds/lb.**
- **Hardly over 2' tall**

Identification

Leaf: Alternate or opposite, short petioled obovate or broadly elliptic, base cuneate, apex obtuse or retuse, margin entire, 3/8" to 1 1/2" long, 3/16" to 3/4" wide, thick and firm, surfaces white with smooth scurf.

Flower: Dioecious, staminate in small sessile heads in spike forming part of terminal, pistillate flowers in leafy elongate terminal spikes; 2 stigmas, staminate flowers in glomerate panicles.

Roots: Nitrogen-fixing endotropic mycorrhizae my occur on roots.

Growing Conditions

- Tolerant of alkaline soils.
- Dominant in eroded desert areas.
- Recommended for the 8" to 15" precipitation zone.
- Good drought tolerance.
- Survives and grows in broad environmental conditions.
- Good soil stabilization.

Reclamation Benefits

- Desert forage for cattle.
- Winter sheep browse.
- Not of great commercial value.

Notes

Mountain Mahogany
Cercocarpus montanus

- **Native perennial shrub**
- **Shrub to Tree size**
- **59,000 seeds/lb.**

Identification

Leaf: Ovate to oval, 25 to 40 mm long, greyish-green upper surface, pilose lower surface; rounded apex.

Flower: Calyx tube 5 to 8 mm long; achenes villous, 8 to 10 mm long. Flowers May and June.

Growing Conditions

- Adapted to all soil textures; best on medium to clayey soils.
- Requires adequate drainage.
- Fair tolerance to saline conditions.
- Recommended for the 10" to 25" annual precipitation zone.
- Very good drought tolerance.
- Drought tolerance make species useful for erosion control plantings on arid mountain slopes.
- Seedling susceptible to drought and frost.
- Germination rate 50-70%; temperatures: mid 70F/days, mid 50F/nights.

Reclamation Benefits

- Wildlife forage and habitat.
- Erosion control, revegetation, and wildlife conservation.
- Good to very good browse for livestock.
- Withstands grazing well.
- Important food source to pinon mouse.

Notes

Rubber Rabbitbrush
Chrysothamnus nauseosus

- **Native shrub**
- **330,000 seeds/lb.**
- **9" to 9' tall**

Identification

Leaf: Alternate, sessile, filiform to broadly linear, 2 to 5 mm long, 0.5 to 1.5 mm wide; densely hairy to subglabrous. Stems erect from base to form rounded clump.

Flower: In cymes rounded or aggregated in thyrses; involucre 6 to 8 mm high; bracts in Imbricate, 20 to 25, lanceolate, firm; flowers 5 to 6, corolla tubular-funnelform, narrow below. Flowers yellow, August to December.

Roots: Deeply rooted perennial shrub.

Growing Conditions

- Adapted to medium to coarse textures and alkaline soils.
- Moderate tolerance to saline conditions.
- Recommended for the 8" to 16" precipitation zone.
- Drought resistant.
- Adapted to dry hills and plains of Northern and Central N.M.
- Elevation from 5,000 to 8,000 ft.
- Germination percentages usually 20 to 40%.

Reclamation Benefits

- Erosion control.
- Fair forage value for deer on winter range.

Notes

Douglas Rabbitbrush
Chrysothamnus vlscldiflorus

- **Native shrub**
- **Deciduous**
- **Several subspecies**
- **Small to large in size**

Identification

Leaf: Linear to lanceolate, twisted or flat, 2 to 5 cm long, 2 to 5 mm wide, acute or acuminate, glabrous on both sides, viscid; ciliolate-scabrous on the margins.

Flowers: Borne in terminal cyme; several outer flower bracts, not in well defined rows, often with a thick brown or green spot near apex. Small, lobed, yellow disc flowers typically five per head bearing hairy five angled achenes surrounded by a ring of hairs. Flowers August and September.

Fruit: 3 to 4 mm long, narrowed to base, 5-angled, densely villous hairy; pappus rigid, whitish, as long as the corolla or longer.

Stems: Twigs ascending to erect, semi-herbaceous, from a multi-branched woody base, whitish. Stems tall to 1 m, brown fibrous bark.

Roots: Medium depth, well branched system.

Growing Conditions

- Broad adaptions to soil texture; occurs on clayey, saline bottomlands to well-drained medium to coarse textured soils.
- Good drought tolerance, varying among subspecies.
- Adapted in 6" to 20" annual precipitation zone.
- Some variability to winter hardiness and frost sensitivity of seedlings.
- Good fire and grazing tolerance due to strong sprouting habits.
- Fair compatibility with associated vegetation.

Reclamation Benefits

- Provides cover for small mammals, lizards and birds.
- Variable use by big game.
- Fair use by sheep, less by cattle.

Notes

Stansbury Cliffrose

Cowanla mexlcana
var. stansburiana

- **Native shrub**
- **64,000 seeds/lb.**
- **To 6' tall**

Identification

Leaf: 10 to 15 mm long, cuneate-obovate In outline, plnnately lobed, glandular-viscid; stems resinous, spreading branches.

Flower: Yellow, perfect, solitary, terminal; densely villous styles, elongate-plumose. Flowers April to July.

Roots: Nitrogen-fixing endotropic mycorrhizae on root nodules.

Growing Conditions

- Adapted to all soils; best on medium to clayey soils.
- Adapted to dry slopes and mesas.
- Tolerant of dry sites in the 11" to 18" precipitation zone.
- Good drought and heat tolerance.
- Grows on harsh, south-facing slopes, on soils of igneous or sedimentary origin.
- Naturally increases on raw spoil.
- Seed in fall or early winter; cover with 1/4" to 1/2" soil.
- Good germination, persistence and natural spread.
- Poor to fair ease of establishment.

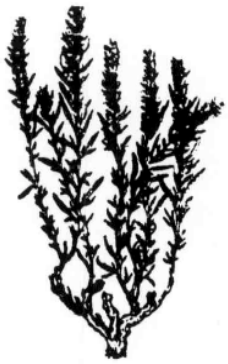
Reclamation Benefits

- Good palatability.
- Provides winter food for big game.
- Recommended for wildlife, grazing and windbreaks.
- Excellent for erosion control on slopes.

Notes

Winterfat

Eurotia lanata
Ceratoides lanata



- **Native perennial shrub**
- **111,000seeds/lb.**
- **1' to 3' tall**

Identification

Leaf: Linear-lanceolate, 15 to 50 mm long, short petiole, entire margins; stems woody at base, erect, densely stellate.

Flower: Densely clustered In upper leaf axils; floral bracts lanceolate, 5 to 8 mm long; densely long-villous, calyx lobes pubescent. Flowering May to October,

Roots: Fibrous with deep taproot.

Growing Conditions

- Adapted to all soil textures.
- Fair to good saline tolerance.
- Good drought tolerance
- Can be established by stem cuttings.
- Plant by seed, cuttings and transplants in fall and spring.
- Collect seed late October to early November.
- Seed at 1/16" to 1/8" (1/4" to 1/2" acceptable).
- Seed may not tolerate long storage.
- Long lived and very adaptable.

Reclamation Benefits

- Utilized by many small and some large game animals in winter.
- High range restoration and soil stabilization value.
- Low to moderate tolerance to grazing.
- Good portability and nutritious.

Notes

Common Chokecherry
Prunus virginiana

- **Native shrub or small tree**
- **Thicket forming**
- **Up to 30' tall**
- **5,200 seeds/lb**.

Identification

Leaf: Alternate, simple deciduous, thin, % to 4 in. long, Vz to 2 in. wide, oval to oblong, acuminate or acute at the apex, cuneate or cordate at base, sharply serrate on the margin. Dark green and lustrous above, turning yellow in autumn.

Flowers: Short, dense, cylindric racemes 3 to 6 In. long. Vi to in. in diameter, on slender pedicels of early deciduous bracts. Small, white corolla, with rounded petals. Flowering April to July.

Fruit: Ripening July-September, cherry 1/4 to in thick, globose, lustrous, dark red, scarlet or nearly black. Thick skin, juicy flesh; Good crops almost annually.

Stems: Twigs reddish brown to orange-brown, slender and glabrous with pale lenticels. Dark gray to brown bark on older bark, older trees irregularly fissured into small scales.

Growing Conditions

- Prefers moist sites in open areas, mountains and along steep canyon walls.
- Adapted to all soil textures, best on deep fertile silty or sandy soils, does poorly on dense clays.
- Does not tolerate poor drainage or prolonged spring flooding.
- Best adapted to the 12 to 30 inch precipitation zone.
- Will not tolerate alkaline soils.
- Fair drought tolerance.

Reclamation Benefits

- Provides very good forage and cover for wildlife including small mammals, bears and many game birds.
- Sometimes planted for erosion control.
- Aggressive root and sucker sprouting after fire and moderately to grazing.

Notes

Antelope Bitterbrush
Pursia tridentata

- **Native shrub**
- **15,000 seeds/lb.**
- **To 3 meters tall**

Identification

Leaf: 5 to 25 mm long, wedge shaped, 3 lobed at apex, whitish-tomentose beneath, short petioled, stems, spreading to erect.

Flower: Petals 5 to 9 mm long, solitary, calyx lobes ovate. Flowering May and June.

Roots: Reported as a host plant for nitrogen-fixing mycorrhizae.

Growing Conditions

- Adapted to all soil textures; best on coarse soils.
- Good on dry slopes.
- Fair tolerance to saline conditions.
- Recommended for the 10" to 12" precipitation zone.
- Good drought tolerance.
- Adapted to low fertility soils.
- Good germination, vigorous seedlings and ease of establishment.
- Growth forms range from low to 15' tree-like plants.
- Drill seeds at 1 inch depth.

Reclamation Benefits

- Good species for wildlife browse and soil stabilization.
- High palatability.
- Tolerant to grazing.

Notes

Skunkbush Sumac

Rhus trilobata
Rhus aromatica

- **Native shrub**
- **20,3000 seeds/lb.**
- **To 2 meters tall**

Identification

Leaf: Strongly pungent when crushed, Alternate, deciduous, trifoliate, 3/4" to 2" long; leaflets cuneate obovate, firm, dark-green and glabrous above, paler and pubescent below. Leaves brilliantly colored in autumn.

Flower: Flowers March & April, numerous borne before the leaves emerge, in terminal spikes, sepals 1 to 2 mm long; petals 2 to 3 mm long, yellowish; fruit 6 to 7 mm in diameter. Red to orange with short glandular hairs.

Growing Conditions

- Adapted in areas of outcropped limestone.
- Adapted to soils of the desert southwest.
- Rocky mountain slopes, widespread; 5,000 to 7,500 ft.

Reclamation Benefits

- 15% of summer diet for mule deer.
- Browsed by mountain sheep.
- Value as livestock browse seems to vary with location.
- Young shoots highly preferred by small animals.

Notes

Wax Currant
Ribes cereum

- **Native shrub**
- **185,595 seeds/lb.**
- **2' to 4' tall**

Identification

Leaf: 10 to 44 mm wide, 3 to 5 lobes, the lobes obtuse, crenate, surfaces glandular-puberulent, alternate. Petioles puberulent. Upright form, deciduous.

Flower: Sepals about 2 mm long, exceeding the petals; anthers with a cup-shaped gland at apex. Bright red berries, 6 to 8 mm in diameter, globose. Flowering May to July.

Growing Conditions

- Poor tolerance to saline conditions.
- Recommended for the 15" annual precipitation zone.
- Drought tolerant.
- Open slopes, ridges or open pine forests.
- Widespread; 5,000 to 9,000 feet.
- Broadcast method of seeding.
- Requires 3 months cold, moist stratification at 40 degrees F; 60% germination rate.

Reclamation Benefits

- Value for wildlife, song and game birds, especially grouse.
- Limited value as browse for mule deer and livestock.
- Erosion control along stream banks.
- Black bear eat berries during summer.

Notes

Black Greasewood
Sarcobatus vermiculatus

- **Perennial shrub**
- **2' to 10' tall**

Identification

Leaf: Deciduous, simple alternate, 0.5 to 1.5" long, 0.1" wide. Linear to filiform, flat above, rounded beneath, margine entire succulent, first puberulent, glabrous later.

Form: Widely spreading branches, rigid, somewhat spinescent, leafy, dense, whitish-tan.

Fruit: Maturing September to October; Green to tan or reddish.

Growing Conditions

- For revegetation on highly alkaline and sodic-saline reclaimed areas.
- Found on dry plains and slopes of grasslands.

Reclamation Benefits

- Not suitable or desirable for most areas as revegetation.
- Forage for livestock in fall and winter.
- Concentrated feeding of leaves and young stems may cause poisoning.
- Wildlife food eaten by porcupine, jackrabbit and chipmunk.

Notes

Fendler Rose

Rosa woodsii
var. fendleri

- **Native shrub**
- **43,500 seeds/lb.**
- **To 1 meter tall**

Identification

Leaf: 5 to 7 foliolate; stipules densely glandular on back, leaflets oval to obovate or elliptic, 10 to 30 mm long, green and glabrous on upper surface, puberulent and glandular beneath, simply or double serrate.

Flower: Flower branches unarmed, flowers solitary or few in a cluster; petals about 15 mm long, 5 petals, pink. Flowers June to August.

Fruit: Hips globose or rarely ellipsoid, glabrous, in fruit 1/3" to 2/5" round.

Growing Conditions

- Plains and mountains slopes; 6,000 to 9,000 ft.

Reclamation Benefits

- Adds to diversity of seed mix in riparian areas.
- Soil stabilization.

Notes

Western Snowberry
Symphoricarpos occidental

- **Native shrub**
- **75,000 seeds/lb**
- **To 1.5 meters tall**

Identification

Leaf: Oval, 3 to 10 cm long, entire to crenate. sinuate, or lobed, obtuse or acute at apex, green and glabrous or sometimes pilose, paler and sparsely pilose beneath.

Flower: Sessile, in dense axillary or terminal clusters. Floral bracts and bractlets oval, ciiiate; corolla pink, 6 to 9 mm long; fruit greenish-white, nearly globose, to 8 mm long. Flowering July and August.

Roots: Fibrous with taproot.

Growing Conditions

- On hills and valleys, sometimes along streams.
- Adapted also to dry rocky soils of bluffs and prairies.

Reclamation Benefits

- Erosion control.
- Good forage for cattle.
- Fruit eaten by 15 species of birds.

Notes

New Mexico Olive

Forestiera neomexicana
F. pubescens var. glabrifolia

- **Native tree or shrub**
- **32,000 seeds/lb.**
- **Up to 12' tall**

Identification

Form: Erect spreading shrub or ascending small tree to 12', often clumped at the base with semispinescent branches. Branches stiff, laterals are shortened, grey to white. Thorny.

Leaf: Simple, opposite, deciduous, spatulate-oblong to ovate-oblong, apex obtuse or short acuminate, 1/2" to 1 3/4" long, 1/4" to 3/4" wide.

Seed: Ripening June to September, drupe 1/5" to 1/2" long, bluish black, ovoid to ellipsoid, obtuse. 1 seeded, germination 40-70 percent.

Growing Conditions

- Adapted to sand, loam and clayey soils, widely spread.
- Mostly in damp ground near streams or in river valleys.
- Hillsides, mesas, moist valleys.
- Recommended for the 10" to 20" precipitation zone.
- Defoliates when stressed for moisture.
- Elevations of 4,000 to 7,000 ft.
- Flowering April and May.
- Propagated from cuttings, layers, or seeds.

Reclamation Benefits

- For use on riparian habitats where sufficient water is available.
- Excellent wildlife cover.

Notes

Utah Juniper
Juniperus osteosperma

- **Native tree**
- **Transplant**
- **To 24' tall**

Identification

Form: Monoecious tree to 8 m tall, crown irregularly conical; branches spreading from a definite trunk. Bark of younger growth scaly, older limbs and stems grey.

Leaf: Foliage stiff, bunching toward ends of branches, scalelike, closely oppressed, crowded, yellowish-green, opposite or sometimes in whorls of 3.

Seed: Berry-like succulent cone. Ripening in autumn of second year, very persistent, reddish brown but appearing bluish because of the thick glaucous coating, 1/4" to 1/3", thin flesh, dry, sweet. Outer seed coat hard and bony.

Growing Conditions

- Dry rocky slopes and open hills.
- Found at elevation of 6.000 to 7,500 ft.

Reclamation Benefits

- Fruit eaten by chipmunk and ground squirrel.
- Leaves occasionally browsed by Black-tailed deer.
- Protection/cover for animals.

Notes

Pinion Pine
Mexican Pinyon Pine
Pinus edulis

- **Native Tree**
- **Transplant**
- **To 30' tall**

Identification

Form: Small straggly evergreen, irregularly rounded or spreading, often beginning at few feet from ground level. Current years growth grey and smooth, older bark reddish-brown to greyish-brown.

Leaf: 2 occasionally 1 or 3 needles per fascicle, stiff, curved, linear, yellowish-green, sometimes slightly glaucous, 2 to 5 cm long, about 1 to 2 mm wide.

Cones: Staminate cones, red or reddish brown, in terminal clusters; pistillate cones maturing in September or October, ovoid-globose, often irregular in outline; seed ovoid.

Growing Conditions

- Adapted to dry often rock slopes and ridges.
- Can be transplanted during dormant period, April to early May and October to November, depending on climatic conditions.
- Use 'ball & burlap' method of transplanting or other similar method. Be careful not to damage or break root-ball.
- Widespread; 5,000 to 8,000 feet.
- Slow growth.

Reclamation Benefits

- The seeds (nuts) are consumed by ground squirrels, chipmunks, porcupine, black bear, quail and merriam's turkey.
- Goats and mule deer browse the foliage.
- Protection/cover for animals.

Notes

Ponderosa Pine
Pinus ponderosa

- **Native conifer tree**
- **Up to 230' tall**
- **Crown: short-conical, rounded or flat topped**

Identification

Leaf: 2- or 3-leaved clusters, rather stout, yellowish green to dark green, bearing stomata on 3 faces, length 5-11", deciduous the second or third year.

Flower: April-June, staminate inflorescences yelow, elongate, pistillate cones paired or clustered, dark red.

Fruit: August-September, cone ellipsoid to ovoid, solitary or clustered, length 3-6", when mature light reddish brown, scales narrow with a thicked apex which is diamond-shaped and transversely ridged;cone deciduous after opening; seeds ovoid, about ¼” long.

Bark: Thick with deep irregular fissures; separating into large, elongate plates, which break into small, oppressed, cinnamon-red to brown or black scales.

Growing Conditions

- Rapid growing at first then slows down considerably when older.
- Drought and fire-resistant.
- Tolerates many types of soil.
- Not very resistant to insects.

Reclamation Benefits

- Used somewhat in shelter-belt plantings.
- Seeds are eaten by many species of birds and small mammals.
- Browsed by mule deer, white-tailed deer, elk and Mountain sheep.

Notes

Gamble Oak
Quercus gambellii

- **Native shrub or tree**
- **To 15 meters tall**

Identification

Form: Very variable; thicket-forming shrub to rounded tree to 50 feet tall, trunk to 2' in diameter. Depending on location. Bark grey and thick, fissures deep, small scales.

Leaf: Young leaves brownish grey, tomentose; older ones deciduous, oblong 2 1/2" to 6' long; 1 1/2" to 3" wide, margin 5 to 9 lobed, upper surface shiny, lower surface duller.

Seed: Acorn. 1/4" to 3/4", round.

Growing Conditions

- Adapted to well drained soils and various soil textures.
- Altitudes of 6,500 to 8,500 ft.
- Many varieties depending on specific location.
- Flowers April to May.

Reclamation Benefits

- Browsed by livestock, Black tail deer and porcupine.
- Excellent wild

Notes

New Mexico Locust
Robinia neomexicana

- **Native tree or large shrub**
- **Up to 24' tall**
- **Thicket forming**

Identification

Leaf: 9-21 leaflets, elliptic to oblong, sometimes oval, alternate, deciduous, odd-pinnately compound, obtuse to rounded at both ends, margin entire, length 3/8-1½ in.

Flower: Large, showy, 2-4" long, all parts pubescent or glandular-hispid. Corolla 8-10" long, rose-pink colored, flowers April-August in axils of the leaves of the current years growth.

Fruit: Legume maturing September-October, 2-4" long, 3/8-2/5" wide, flat thin, glandular-hispid, thickened on one edge, 2 vaived, 4-8 seeded.

Stems: Twigs with straight or sometimes curved stipular spines; young twigs puberulent, becomming reddish-brown and finally grey.

Growing Conditions

- Generally found in moist soil along streams growing in sunny areas.
- Grows at altitudes of 4,000 to 8,500 feet in canyons & open woods.
- Propagate by seed in well drained, fertile, sandy loam soils, 9-12 inches apart and covered with 1/4" of soil.
- No mulch or shade required for germination.

Reclamation Benefits

- Valuable for erosion control.
- Browse for Gamble's quail, mountain sheep. Black-tailed deer, chipmunk and porcupine.
- Reported to be used as a remedy for rheumatism by the Hopi Indians.

Notes

Downy Chess Cheatgrass
Bromus tectorum

- **Cool season**
- **Annual**
- **Introduced from Europe**
- **Aggressive weed species**

Identification

Leaf: Leaf blade and sheaths densely covered with soft pubescent, 3 to 6 mm wide; Blade is flat, 5 to 12 cm long and 3 to 7 mm wide.

Seedhead: Inflorescence is dense, slender, usually drooping, 1-sided, 2 to 6 inches long, contain seed, to % inches long, with awns up to Inches long.

Roots: Shallow rooted annual.

Ligule: Membranous, 2 to 3 mm long, acute, erose to lacerate.

Sheath: Round, keeled toward collar, densely covered with soft hair.

Growing Conditions

- Widely distributed throughout North America and is common along roadsides, waste areas, misused pastures and rangelands, and cultivated crop areas.
- Seeds germinate in fall or early spring.
- Rapid spring growth with seeds maturing in about 2 months.
- Competes with more desirable perennial grasses for moisture because of its winter and early spring growth habit.
- Common crop seed contaminant, especially abundant in crested wheatgrass and bromegrass.

Reclamation Benefits

- On certain intermountain ranges it has become the primary green foraged utilized by livestock.
- Moderate grazing tolerant.
- After maturity it becomes a fire hazard.

Common Chokecherry

Notes

Broom Snakeweed
Gutierreziz sarothrae

- **Native**
- **Warm season shrub**
- **Perennial weedy shrub**

1" to 2" tall

Identification

Leaf: Alternate, narrow and untwisted, 1 to 1½ inches long and are green with smooth margins, slightly rolled to the center and are located on the upper parts of the plant.

Flowers: Pistillate and perfect, heads inconspicuously radiate; involucre 3 t0 6 mm tall, 2 mm wide; in 5 series of 4 bracts; bracts linear 1.2 to 3.5 mm long; acute, imbricate, with green mid-rib and tip; ray flowers 3 to 7 , pistillate, ligule yellow, 2 mm long; disk flowers 2 to 6 , perfect, corolla yellow.

Fruit: Oval and covered with chaffy scales.

Stems: Twigs slender, herbaceous above, woody below, scurfy grayish green or whitened at first, later glabrous to dark brown or gray and roughened below.

Growing Conditions

- Considered an evergreen in New Mexico and Arizona
- Reproduces bu seed and root systems.
- Occur over most of the state from 3,000 to 8.000 feet.

Reclamation Benefits

- Common snakeweed is a poisonous plant which is most toxic during leaf formation.
- Pastures are not porperly utilized when this weed is found within the grasses.
- Control of this species can be attained with herbicides.

Notes

Halogeton

Halogeton glomeratus

- **Annual weed species**
- **Introduced from Asia**
- **Warm season**

Identification

Leaf: Leaves are small, fleshy, and nearly tubular, ending abruptly, tipped with a delicate needle-like spine. Succulent, ¼ to ½ inch long.

Flowers: Green and inconspicuous, borne in leaf axils. Plants resemble Russian thistle in early stages but they can be distinguished by leaf shape, and by the presence of minute cottony hairs in the leaf axils. Plants are blue-green in the spring and early summer, turning red or yellow by late summer.

Fruit: Winged, conspicuous, often mistaken for flowers, basally enclosing single seed.

Stems: Annual herb with thick, juicy stems; branching from the base, at first spreading, then usually becoming erect. Stems measuring a few inches to more than a foot long, generally with numerous short lateral branches.

Roots: Medium depth, well branched system.

Growing Conditions

- Seems ideally adapted to the alkaline soils and semi-arid environment of high-desert winter livestock ranges.
- Drought and alkaline tolerant.
- Adapted to precipitation zones of less than 6"

Reclamation Benefits

- Dangerous at all times, but becomes more toxic as the growing season advances, reaching a peak of toxicity at maturity.
- All above-ground parts are toxic, but the greatest concentration is in the leaves and fruiting structures.
- Highest livestock losses occur In late fall and early winter when hungry animals are driven along trails, or bed down in infested areas.

Notes

Kocia
Kochia scoparia

- **Introduced from Eurasia**
- **Warm season**
- **Annual (Chenopodiaceae)**
- **Forb, usually 1 to 3 feet tall**

Identification

Leaf: Alternate, lance shaped, simple, entire V2 to 2 inches long, margins fringed with hairs; the upper surface is usually smooth, the lower surface usually covered with soft hairs.

Flower: Inconspicuous, sessile in the axils of upper leaves and form short, dense, bracted spikes.

Fruit: Utricle; depressed-globose, enclosed in a 5-winged persistent pericarp,

Stem: Can reach 6' tall, erect, much branched, round, slender, usually soft-hairy, but occasionally smooth, often has a red-tinge.

Growing Conditions

- Escaped ornamental, common in cultivated fields, gardens, roadsides, ditch banks and waste areas throughout the western U.S.
- Highly moisture dependent
- Reproduces from seed
- Drought tolerant
- Adapted to all soil textures, does best on course soils.

Reclamation Benefits

- Readily grazed by livestock when immature
- Generally considered a weed species
- Palatable to livestock and is highly productive and nutritious during early growth in spring.
- Sometimes contains high nitrate levels and can be toxic, causing bloat and photosensitization.
- Most toxic during drought and at seed maturation.

Notes

Russian Thistle Tumbleweed

Salsola Iberica

- **Introduced from Eurasia**
- **Warm season**
- **Annual (Chenopodiaceae)**
- **Forb ½ to 3 feet tall**

Identification

Leaf: Leaves are alternate; first are long, string-like and soft, with later leaves short, scale-like and tipped with a stiff spine.

Flower: Inconspicuous white to pink flowers are borne in axils of upper leaves, each flower accompanied by a pair of spiny bracts.

Fruit: Utricle; ovoid or orbicular, 1.5 to 2.5 mm wide, flattened. Persistent perianth forming 5 wings, 3 to 6 mm wide.

Stalk: Tall, erect, Vi to 3 feet tall, much branched stems are usually red or purple striped.

Growing Conditions

- Seeds are spread as mature plants break off at ground level and are scattered by wind as tumbleweeds.
- Rapid germination and seedling establishment occur after only brief and limited amounts of precipitation.
- Well adapted to cultivated dryland agriculture, but Is also found on disturbed wastelands, overgrazed rangeland, and even some irrigated cropland.
- First introduced into South Dakota in flax seed.
- Adapted to all soil types.

Reclamation Benefits

- Generally considered a weed species.
- May accumulate nitrates and may contain oxalates.
- Fair for cattle and sheep in early spring, becoming worthless because of sharp leaves.

Notes

Appendix A

Soil and Topsoil Suitability Ratings Primary Root Zone

Characteristic	Good	Marginal	Generally Toxic/Unacceptable
pH (saturated paste)	6.0-8.4	5.5-5.9 8.5-8.8	<5.5 >8.8
E.C.[2] (mmhos/cm)	< 4.0 wlth SAR	> 4.0 with SAR	>12.0 with SAR
<20% clay	<12	<18	>18
20-35% clay	<10	<16	>16
>35% clay	<8	<14	>14
Textures:	with < 35% clay	> 35% clay < 45% clay	> 45% clay or < 6% clay >85% sand
Saturation Percent	25-80		< 25 or > 80
Course Fragments[3] <3 Inch >3 Inch	 >15% < 3%	 15-35% 3-10%	 >35% >10%
Acid-Base Potential	+5 T $CaCO_3$ equlv./l000t	+0 T $CaCO_3$ equlv./l000t	- $CaCO_3$ equlv./l000t

[1] For the purposes of this guidance, the primary root zone is defined as the upper part of the rebutt "soil" column equal in depth to 2.5 times the average annual precipitation.

[2] When high sodicity is a problem, an electrical conductivity lower than 2 mmhos/cm intensifies the problem.

[3] Depends on post mine land use.

Appendix B

Soil & Topsoil Nutrient Suitability Ratings Primary Root Zone[1]

Characteristics	Low	Coop	High	Unsuitable	Extract Method
Nitrate-NO_3 (N)	9	9-18	> 18		Water extract
Phosphrous (P)	0-15 6	16-30 6-11	> 30 > 11		Bray Sodium bicarbonate
Potassium 00	60	61-120	>120		Ammonium acetate. Sodium acetate
Selenium (Se)	total	<0.2	0.2-0.8	> 0.8	Perchloric digest
	water soluble	<0.1	0.1	> 0.15	Hot water
Boron (B)	<0.1	0.1-5		<0. 1 or >5	Hot water
Iron (Fe)	2.0	2.0-4.0		> 4.0	DTPA
Magnesium(Mg)	25	25-50	> 50		Ammonium acetate
Manganese (Mn)	0-0.75		> .75	> 10-60	DTPA
Copper (Cu)	0-0.2		> 0.2	> 10-40	DTPA
Cadmium (Cd)				> 0. 1-1.0	
Lead (Pb)				> 10-20	
Mercury (Hg)				> 0.4-0.5	
Molybdenum (Mo)	0.1		0.1-0.2	> 0.3	
Nickle (Ni)				> 1.0	
Arsenic (As)			>2.0-9.5		

[1] Generally unsuitable without mitigation to bring into suitability guidelines.

Appendic C

Ions and Elements of Soil Chemistry

Major Exchangable Cations	**Major Anions**	
Ca^{2+}	NO^{3}	Important nutrient sources for plants
Mg^{2+}	SO_4^{3-}	Important nutrient sources for plants
Na^{+}	Cl^{-}	accumulate in saline soils
K^{+}	HCO_3^{-}	accumulate in saline soils
NH_4^{+}	CO_3^{2-}	present in appreciable amounts with pH >9
$Al^{3+}(H^{+})$	characteristic cation in acid soils	

Weakly Soluble Anions

$H_2PO_4^{-}$, HPO_4^{2-}	strongly retained by soils; retention or fixation is pH; dependent;	
$H_2AsO_4^{-}$, AsO_2	phosphate is more soluble at neutral or slightly acid pH	
		<u>Toxic Ions</u>
H_3BO_3, $H_2BO_3^{-}$	most soluble of the group	Cd^{2+}, Al^{3+}: plant toxicity
$Si(OH)_4$	more soluble at high pH	Pb2'
MoO_4^{2-}	more soluble at high pH	Hg^{2+}, Hg
		Be^{2+}, AsO_4^{3-}, CrO_4^{3-}

Transition Metals and Aluminum

Al^{3+}, $ALOH^{2+}$, $AI(OH)_2^{+}$	hydroxides tend to accumulate as silica
$TlOOH^{+}$	more soluble in waterlogged or reduced soils
$Fe(OH)^{2+}$, Fe^{2+}	more soluble in waterlogged or reduced soils
Mn^{2+}	more soluble than the above cations in all but very acidic soils;
Cu^{2+}	availability increases with increasing soil acidity;
Zn^{2+}	complexed strongly by soil organic matter__

Active in Oxidation-Reduction Reactions

C (organic to HCO_3^{-})	soil biochem. revolves around the oxidation state of C, N & S.
N (-NH_2 to NO_3^{-})	
S (-SH to SO_4^{2-})	
O (O^{2-} to O_2)	molecular oxygen is the main electron acceptor
Fe (Fe^{2+} to FeOOH)	
Mn (Mn^{2+} to $MnO_{1.7}$)	
Se (organic to SeO_4^{2-})	
Hg (organic to Hg^{0} or Hg^{2+})	

Appendix D
Typical Reclamation Seed Mix

Seed name	Growth form	A Bulk Seeds/lb	B % Purity	C % Germ	D Density PLS[1]/lb.	E Application rate PLS/Ac	F Application rate PLS/ga.ft.
Drill Seed Mix							
Western wheatgrass	C	110,500	96	95	100,320	2.17	55
Indian ricegrass	C	141,500	95	99	132,610	0.98	3.0
Needle and thread	C	116,500	80	95	87x100	0.49	15
Arizona Fescue	C	550,500	84	94	434,280	0.40	2.0
Blue grama	W	825,500	93	66	506,385	0.52	6.0
Sideoats grama	W	143,500	85	83	100,887	1.29	3.0
Galleta grass	W	159,500	89	80	113,208	0.77	2.0
Fourwing saltbush	S	52,000	60	98	30,576	0.71	0.5
Antelope bitterbrush	S	15,500	93	95	13,252	3.28	1.0
Cliffrose	S	64,500	70	90	40,520	0.54	0.5
			Subtotal Drill Mix:			11.15	24.0
Broadcast Seed Mix							
Alkali sacaton	W	1,750500	98	91	1,560,650	0.11	4.0
Sand dropseed	W	5500500	97	82	3,977,000	0.05	5.0
Swrtchgrass	W	389,000	92	98	350,722	0.25	2.0
Blanket flower	F	132,500	73	92	88,651	0.49	1.0
Blue flax	F	293,000	96	82	230,649	0.18	1.0
Rocky Mt penstemon	F	592,500	95	92	517,408	0.04	0.5
Purple prairie clover	F	300,500	95	92	262,200	0.08	0.5
Prairie coneflower	F	1,230,500	95	98	1.145.130	0.03	1.0
Scarlet globemailow	F	600,500	95	95	451,250	0.10	1.0
Winterfat	S	111,500	77	80	68.376	1.27	2.0
			Subtotal Broadcast Mix:			2.60	18.0
			Total Seed Mix:			13.92	42.0

[1] = Pure Live Seed

Seed Mix Calculations: Column D = Column A X B X C

Column E = $\frac{\text{Column D X E}}{43360}$

Seed Mix Diversity

Growth Form	**# of Species**	**% of Mix PLS/93.ft**
w = Warm season grasses	6	52.38
c = Cool season grasses	4	26.20
i = Shrubs	4	9.52
r = Forbs	6	11.90
Totals	20	100.00

Appendix E

General Reclamation Planning Calendar

Activity	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
Warm Season Species Seeding				----------(----------	----------)---------							
Cool Season Species Seeding				------(----------	----------)-----							
Shrub Species‡ (Tubling/Seedlings)			----------						----(---------)----			
Mulching				(----------	----------)							
Topsoil Handling†			----------(----------	----------)---------					(----------	----------)		
Addition of Soil Amendments††			(----------	----------	----------	----------	----------	----------	----------	----------	----------	----------)
Seed Bed Preparation†			(----------	----------	----------	----------	----------	----------	----------	----------	----------	----------)
Vegetation (Seasonality)			(------ Cool	------)					(------ Warm	-------)		
Topsoil Samplings§			(----------	----------	----------	----------	----------	----------	----------	----------	----------	----------)

-{-}- = timing: secondary (primary) secondary
‡ = species and climate dependant
† = depending on soil conditions
‡‡ = timing is critical for most amendments
§ = conducted prior to. if applicable, and following redistribution.

Appendix F

Pure Live Seed Calculation Formula

Pure Live Seed Calculation Formula

$$\frac{\text{Sq. ft./acre X P.LS. desired/sq. ft}}{\text{Seeds/lb. X Purity X Germination}} = \text{\# lbs /acre}$$

Example:

Acre = 43,560 sq. ft.
Desired P.LS./sq ft = 10 of Western wheatgrass
Western wheatgrass = 110,000 seeds/lb
Purity = 95% or 0.95
Germination rate = 80% or 0.80

$$\frac{\text{43,560 sq.ft X 10 P.LS./sq. ft}}{\text{110,000 seeds/lb X 0.95 X 0.80}} = \frac{435{,}600}{83{,}600} = 5.21 \text{ lbs./ac.}$$

Answer: **5.21 lbs. of bulk seeds/acre of Western wheatgrass**

Appendix G

Benefits of Mulching Practices

1. Decreases water and wind erosion.

2. Increases moisture infiltration.

3. Increases soil moisture by decreasing evaporation.

4. Keeps soil surface cooler during summer and warmer during winter.

5. Increases soil organic matter.

6. Increases carbon supply that microbes use in beneficial soil functions.

7. Increases cation exchange capacity of soil; 30-70% of sites furnished by organic matter.

8. Increases aeration in soil.

9. Increases available water in sandy soils.

10. When crimped, improves seed-to-soil contact, which improves germination rate.

11. Improves soil tilth.

12. Intercepts and decreases velocity of raindrops, decreasing splash erosion.

13. Prevents soil crusting, which can hinder seed germination and seedling emergence.

Appendix H

Soil Organic Matter

General Properties of Humus and Associated Effects in the Soil[a]

Property	**Remarks**	**Effect on Soil**
Color	The typical dark color of many soils is caused by organic matter.	May facilitate warming
Water Retention	Organic matter can hold up to 20 times its weight in water.	Helps prevent drying and shrinking; improves moisture retention in sandy soils
Combination with clay minerals	Joins soil particles into structural units known as aggregates	Permits gas exchange; stabilizes structure; increases permeability
Chelation	Forms stable complexes with Cu2+, Mn2+, Zn2+, and other polyvalent cations	Buffers the availability of trace elements to higher plants
Solubility in water	Insolubility of organic matter results partially from its association with clay; salts of divalent and trivalent cations with organic matter are also insoluble in water.	Little organic matter is lost by leaching.
pH relations	Organic matter buffers soil pH in the slightly acid, neutral, and alkaline ranges.	Helps to maintain a uniform reaction (pH) in the soil.
Cation exchange	Total acidities of isolated fractions of humus range from 3,000 to 14,000 mmhos kg^{-1}.	Increases the cation exchange capacity (CEC) of the soil: from 20 to 70% of the CEC of many soils is caused by organic matter.
Mineralization	Decomposition of organic matter yields CO2, NH4+, NO3- PO43-, and SO42-	A source of nutrient elements for plant growth
Combinations with organic molecules	Affects bioactivity, persistence, and biodegradability of pesticides	Modifies the application rate of pesticides for molecules effective control

[a]From F.J. Stevenson, Humus Chemistry. Wiley, New York, 1982.

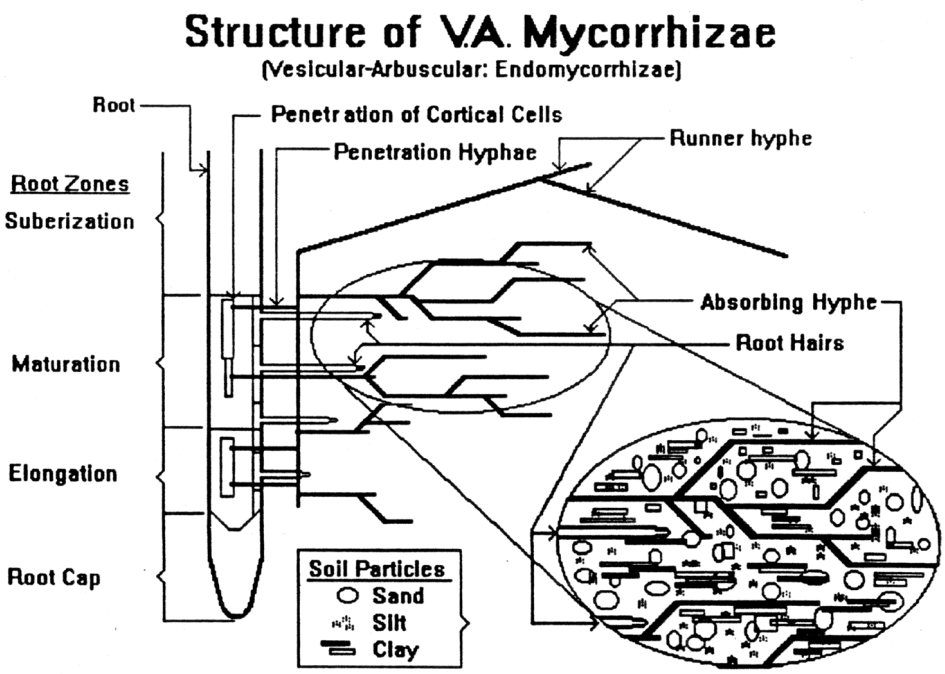
Appendix I

Role of Mycorrhizae in Soil and Plant Interaction

The extent mycorrhizae plays in soil and plant Interactions is not fully known. But, there is substantial evidence that mycorrhizae does Interact highly in several of the community interactions and mineral cycling.

Mycorrhizae is an integral part of mined land reclamation succession. The development of a mycorrhizae population in reclaimed soils supports the ecological building blocks known to stimulate succession. Fungal, plant & animal community interactions, along with carbon, nitrogen, & phosphorus cycling create favorable conditions for plant growth and community development.

Often the importance of the soil fauna is overlooked as part of successful reclamation. The self-introduction of burrowing animals, wind and use of direct haul of topsoil to new reclamation areas will assist In the reestablishment of this important member of land reclamation.



Glossary

A

Achene..... A dry, indehiscent, one seeded fruit with the pericarp free form the seed.
Acid soil..... Generally, pH less than 7,0
Acorn..... A one-seeded nut partially enclosed by a bracteate cupule; the fruit of the oak.
Acrid..... Sharp to the taste.
Acuminate..... Tapering to a long point.
Acute..... Having a leaf apex or base sharp pointed but not tapering.
Adherent..... Attached.
Adventitious..... Developing In other than the regular or usual position.
Alkaline soil..... Generally, pH greater than 7.0; basic soil.
Alternate ..... Referring to organs (such as leaves) occurring singly at a node; referring to any orientation of parts other than opposite or whorled.
Annual..... A plant completing its life cycle in one season.
Anther..... The saclike portion of the stamen containing the pollen.
Apical..... At the tip or apex.
Appressed..... Borne flat against a structure.
Approximate..... Parts occurring near each other.
Arid..... 10" per year average or less precipitation.
Aristate ..... Bearing a stiff bristle; owned.
Armed ..... Bearing sharp appendages.
Articulated..... Jointed or having points of separation.
Ascending..... Angling upward; neither erect nor spreading.
Asexual..... Without sex; with neither functional stamens nor pistils.
Auricle..... An ear-like lobe or appendage.
Awn ..... A bristle-like appendage.
Axil..... The angle formed between any two attached organs.
Axillary ..... Occurring In the axil.
Axis.....The central part of a longitudinal structure.

B

Barbed.....Having reflexed or retrorse points.
Bark .....External tissues, especially In woody plants, containing the outer corky layers.
Basal.....Referring to the base or point of origin of organs.
Berry .....A fleshy, indehiscent fruit, usually from a superior ovary.
Bl.....A prefix meaning two, twice, or doubly.

Biennial..... A plant completing develop.nent in two years.
Bipinnate ..... Twice pinnate.
Bipinnatifid ..... Twice pinnatifid, i,e with each lobe again lobed.
Bisexual..... Having both sexes In the same flower.
Blade ..... The expanded portion, especially of the leaf.
Bract ..... A modified leaf, usually subtending a flower or group of flowers.
Bracteate ..... Having bracts.
Bractlet..... A small bract, usually a secondary bract.
Browse..... Tender shoots, twigs and leaves of trees and shrubs for animals.
Bud..... An unexpended or undeveloped organ such as a branch, leaf, or flower.

C

Calcareous ..... Characterized by significant amounts of calcium carbonate deposits.
Calyx..... Outer whorl or perianth parts; the sepals inclusive.
Canescent ..... With oppressed pubescence giving a grayish appearance.
Carbonates..... Calcium and magnesium which are not combined with soil; >10% may indicate excess carbonates.
Carpel ..... A simple pistil.
Carpellate..... Possessing carpels.
Caryopsis ..... A dry/ one-seeded, indehiscent fruit, with the pericarp thin and adherent to the seed; sometimes called a grain.
Cell..... As applied to a cavity within the ovary of a flower; locule.
Chaff..... Dry scalelike bracts.
Cilia ..... Marginal hairs or bristles, typically conspicuous.
Ciliate..... Having cilia.
Ciliotate..... Minutely dilate.
Clasping..... Embracing the stem.
Clay..... Soil particle less than 0.002mm; microscopic.
Cleft..... Indented about halfway to the base or midrib.
Coarse soils..... Characterized by having sandy, sand loam or soils with good drainage and low water holding capacity.
Collar..... The exterior sirie of a grass leaf, where the sheath and blade join.
Column ..... A linear structure formed from the union of parts, such as stamens or stamens and pistil; a structure subtending the awns In certain grasses.
Complete flower..... A flower having all floral organs present.
Compound .....Composed of two or more similar parts united into a whole.
Compressed..... Flattened.
Cone..... The fruiting structure of many gymnosperms, composed of a series of scales arranged on a central axis; a strobilus.

Congested..... Crowded together.

Conglomerate..... Densely clustered together.

Conic; conical..... Having the shape of a cone.

Coniferous..... Bearing cones.

Contracted..... Narrowed or shortened.

Convolute ..... Rolled up lengthwise.

Corolla.....The inner whorl of perianth parts; the petals as a whole.

Coroniform..... Crown shaped.

Corymb ..... A flat-topped or convex inflorescence, with the lower pedicles longer than the upper ones and the outer flowers maturing first.

Creeping.....With stems running along or near the surface of the ground, often rooting at the nodes.

Crenate..... With rounded teeth.

Crown..... The base of a stem; a coroniform pappus in Compositae; the canopy of a tree; a circle of appendages In the throat of a corolla.

Culm..... The flowering stem of grasses or sedges,

Cuneate..... Wedge shaped.

Cupule .....The involucral cup of the acorn.

Cylindric..... Elongate and circular in cross section; shaped like a cylinder.

Cylindroid ..... Cylinder-like or cylinder shaped.

Cyme..... An inflorescence with the central flower older than the laterals.

Cymose..... Cymelike or bearing cymes.

D

Deciduous.....Falling off.

Decumbent..... Referring to stems with the base postrate but the terminal part erect or ascending

Dehiscent.....Opening regularly by valves or slits, usually applied to fruits or anthers.

Dentate..... Toothed, the teeth having approximately equal sides.

Denticulate ..... Diminutive of Dentate.

Determinate.....Having an inflorescence with the oldest flower in terminal or central position.

Di..... A prefix meaning "two" or "double".

Dichasium ..... A cyme having two lateral axes.

Digitate..... With separate parts or lobes diverging from a common point of origin.

Dioecious ..... Having unisexual flowers with each sex produced on different plants.

Disciform ..... Depressed and circular like a disk.

Disk .....A fleshy or glandular enlargement of the receptacle or hypanthium, often forming a ring around the ovary; the central portion of many

Compositae.

Dissected..... Divided into many fine segments.

Divided .....Separate to the base or nearly so.

Dorsal.....Relating to the Back; abaxil.

Drought..... A prolonged period of dry soil conditions.

Drupe..... A simple, fleshy fruit, with seed enclosed in a bony endocarp.

E

EC ..... Electrical conductivity; Measure of conductance (salt) of the soil saturation extract in mmhos/cm.

Edaphic ..... Related to soil conditions.

Ellipsoid .....Referring to a solid with an etliptical outline. ~

Elliptic .....Shaped like an ellipse.

Endemic..... Restricted to on geographical area.

Endocarp.....The bony inner wall of the pericarp.

Entire.....With an unbroken margin.

Epidermis.....The outer layer of cells of various organs.

Erect..... Arranged in upright position.

Erose..... With irregular margins.

Erosion ..... The wearing away of the land surface through wind, water, ice and gravity.

Erosion K factor..... The ease with which a soil can be eroded. 1.0 most easily eroded, 0.01 almost non-erosive.

ESP .....Exchangeable sodium percentage; measure of exchangeable sodium Ions in relation to the cation exchange capacity in the soil.

Ex.....Prefix meaning "without".

F

Fascicle..... A cluster or bundle.

Fertile..... Sexually protective; capable of sexual reproduction.

Fibrous..... Resembling fibers or composed of fibers,

Filament .....The stalk of an anther.

Filamentous..... Composed of threads; threadlike.

Filiferous .....Having threadlike structures, as the leaf margins of yucca.

Filiform..... Threadlike.

Fine soils .....Characterized by clayey, high water holding capacity and poor drainage.

Fissured .....Cracked.

Floral bract.....A modified leaf subtending a flower cluster of flowers.

Floret.....Any small flower, especially in grasses.

Floriferous.....Flower bearing.
Foliar.....Relating to a leaf.
Foliate..... Referring to leaves.
Forage..... Gathering of food for animals by grazing or browsing.
Forb.....An herb other than grasses.
Fruit.....A mature ovary.
Frutescent..... Shrubby; becoming shrubby.
Furfuraceous..... Consisting of or covered with flaky particles.
Funnelform..... Shaped like a funnel.

G

Glabrate.....Becoming glabrous; having few hairs.
Giabrescent..... Tending to be or to become hairless.
Glabrous.....Without pubescence.
Gland .....A surface or structure capable of secretion.
Glandular..... Bearing glands.
Glaucous ..... Having a bluish or grayish waxy coating.
Globose..... Spherical or rounded.
Glomerate..... Densely clustered.
Glomerulate..... In small clusters.
Glomerule..... A compact rounded cluster of flowers.
Glumes.....The bracts subtending the splkelet ir grasses.
Grain..... See caryopsis.

H

Habit..... The general appearance or aspect of a plant.

Habitat..... The kind of locality in which a plant grows.

Head..... A dense cluster of flowers subtended by an involucre, the flowers sessile on a common receptacle.

Herb..... A non-woody plant.

Herbaceous ..... Not woody; sometimes meaning green in color.

Hip..... The fruit of the rose; an accessory fruit in which several achenes are borne within a nearly closed receptacular cup.

Hirsute.....With bristly hairs.

Hispid.....With stiff, spreading, bristly hairs.

Hispidulous.....Minutely hispid.

Homo..... A prefix meaning "the same".

Homogeneous..... All of one kind.

Husk.....The outer covering of certain fruits.

Hyaline .....Thin, tending to be translucent.

Hybrid..... A cross between two taxa.

I

Imbricate..... With overlapping edges.

Imperfect..... Referring to a flower having only one functional sexual type.

In..... A prefix meaning "in" or "not".

Incised..... Sharply, deeply and Irregularly cut.

Incomplete flower... A flower having one or more of its organs missing.

Indehiscent..... Not dehiscent; not splitting open.

Indeterminate..... Referring to an inflorescence with the terminal or central flower the youngest.

Indigenous..... Native.

Infertile.....Not viable; not fertile.

Inflorescence..... A flower cluster.

Inter ..... A prefix meaning "among" or "between".

Intemode..... The area between two nodes.

Inverted..... Upside down.

Involucre..... One or more series of bracts subtending an inflorescence, as in Compositae and Umbelliferae.

Involute..... Rolled lengthwise.

Irregular..... Showing differences in size or shape of similar parts.

Iso .....A prefix meaning "equal".

J

Joint..... A point of articulation.
Jointed ..... Having joints; with nodes obviously swollen.

K

Keel..... A sharp crease or ridge.

L

Lacerate..... Appearing Irregularly torn.
Lanate..... Woolly.
Lanceolate..... Lance shaped, broadest below the middle.
Lanulose..... Somewhat woolly.
Lateral..... Borne on the sides; referring or belonging to the side.
Layer..... Produce roots where stems contact soil.
Leaflet..... A division of a compound leaf.
Legume..... A dry dehiscent fruit, on carpellate and splitting along two sutures; members of the Leguminosae.
Lemma ..... A bract subtending or enclosing a flower in grasses.
Ligulate..... Strap shaped.
Ligule..... An appendage at the apex of the sheath of grasses; the ray of certain flowers in the Compositae.
Linear..... Slender; having parallel sides with the length usually between eight and ten times the width.
Lobe..... A segement of an organ, resulting from partial division.
Locule..... A cavity within an organ, such as an ovary.
Lustrous..... Shining.

M

Marginal..... Near the margin.
Marglnate ..... Having a distinct margin or edge.
Median..... Pertaining to the middle.
Membranous;
membranaceous.... Thin, flexible, and translucent.
Mesic..... Characterized by a moderate moisture supply.
Mono .....A prefix meaning "one".
Monoecious..... Having unisexual flowers, with both sexes on the same plant.
Mulch..... A protective covering of dry grass, straw or hay spread and left on ground to reduce erosion, evaporation and maintain even soil temperatures.

Mycorrhiza ..... A symbiotic fungi with roots.

N

Nodding..... Hanging down.

Node.....The joint of a stem; the place of leaf attachment.

O

Ob.....A prefix meaning "inverted".

Oblanceolate ..... Lanceolate but attached at the narrow end.

Oblique .....Slanted, with sides unequal.

Oblong ..... Elongate, the sides relatively parallel, the length less than ten times the width.

Obovate.....Inverted ovate.

Obtuse.....Blunt, especially at the apex.

Opposite..... With organs in pairs on either side of a node; also referring to stamens inserted opposite the petals.

Orbicular..... Circular in outline.

Oval..... Broadly elliptic, the width more than half the length.

Ovary..... The basal part of the pistil; that part containing the ovules.

Ovate ..... Egg shaped, broadest below the middle.

Ovid..... A solid with an ovate outline.

Ovule..... An Immature seed.

P

Palatable..... Pleasant to the sense of taste.

Pale..... A chaffy scale.

Palea .....The inner member of a pair of bracts subtending each floret in grasses.

Paleaceous..... Chaffy; with membranous scales.

Palmate.....See Digitate.

Panicle .....Usually applied to any compound inflorescence; a compound raceme.

Paniculate..... Resembling or borne in a panicle.

Papilionaceous;
papilionate.....Referring to a corolla composed of a standard, keel, and wings, as in the corolla of certain Leguminosae.

Parasitic..... Deriving nourishment from and often growing on another plant.

Parted..... Lobed more than halfway to the midrib or base.

Pedicel.....The stalk of a single flower.

Peduncle..... The stalk of a cluster of flowers, sometimes of a single flower If representative of a reduced cluster.

Perennial..... A plant which lives for more than two years.
Perfect..... Referring to a flower with both functional stamens and functional pistils.
Peri.....A prefix meaning "around" or "enclosing".
Perianth..... The calyx and corolla taken collectively.
Pericarp.....The wall of a mature fruit.
Peripheral.....On or near the margin.
Persistent..... Remaining attached longer than typical.
Petal..... A single unit of a corolla.
Petiole ..... The stalk of a leaf. pHMeasure of hydrogen ion activity in the soil. Larger concentration of H+ ions, Acid; OH ions, Alkaline.
Phreatophyte..... A deep-rooted plant obtaining its water from the permanent water table.
Pilose..... Sparsely soft-hairy.
Pinna ..... A primary division of a pinnate or compoundly pinnate frond or leaf.
Pinnate..... With leaflets arranged in two rows along a common axis.
Pinnatifid .....Cleft, divided or Incised in a pinnate manner.
Pistil..... The female reproductive organ of a flower.
Pistillate ..... Referring to flowers with only the pistil present or functional.
Pith.....The spongy center of a stem.
Plaited ..... Folded lengthwise and usually flattened.
Plumose..... Feather-like; having lateral appendages similar to the barbs of feathers.
Pod ..... A dry dehiscent fruit.
Pollen..... The male gametophytes found in the anther.
Poly ..... A prefix meaning "many".
Polymorphous..... With many or various forms.
Precipitation zone... A subdivision of a biogeographic region where rain, hail and snow are deposited.
Primary ..... The main part; the firs part developed,
Process..... An outgrowth or appendage.
Prominent..... Obvious; noticeable.
Prostrate ..... Lying flat on the ground.
Puberulent..... Finely pubescent.
Puberulous .....With minute hairs.
Pubescence..... A covering of soft hairs.
Pubescent..... Covered with soft hairs; a general term meaning hairy.
Pungent.....Ending in a sharp rigid point; acrid.
Pustular..... Blister-like.
Pustulate..... Having pustules.
Pyramidal..... Pyramid shaped.

Q

Quadr ..... A prefix meaning "four".

Quadrate..... Four-sided; square.

Quinquefoliolate..... Having five leaflets.

R

Raceme..... An inflorescence having an elongated axis, with flowers on simple pedicles along the axis.

Racemose.....In racemes or resembling a racme.

Rachilla .....Referring to a small rachis in the spikelet of grasses.

Rachis.....The axis of a compound leaf or spike.

Radiate..... Having rays; spreading from a common point.

Ray..... A ligulate marginal flower; the branch of an umbel or similar inflorescence.

Receptacle .....The shortened floral axis to which the floral parts are attached.

Regular..... Having radial symmetry.

Remote..... Distantly space.

Resinous..... Producing resin.

Retrorse .....Directed downward or backward.

Refuse..... Having a rounded sinus at the apex, as a leaf blade.

Revolute .....Having the edges rolled under.

Rhizomatous..... Having rhizomes.

Rhizome .....A more or less horizontal underground stem.

Ribs.....The prominent veins of a leaf; linear ridges on fruits.

Ribbed..... Having ribs.

Riparian..... Growing on the bank of a stream or lake.

Root .....The descending axis of the plant, usually underground.

Rootstock..... A rhizome; an elongate, rooting, underground offshoot.

Runner..... A slender stolon.

S

Samara..... A winged, dry, indehiscent fruit.

Saprophyte ..... A plant living on dead organic matter.

Saline..... Soils containing sufficient soluble salts >4dS/m.

Saline-Sodic..... Soil containing both saline and sodium at high concentrations.

Sand ..... Soil particles between 2.00.05mm In size.

SAR .....Sodium absorption ratio; Sodium content relative to its calcium and magnesium content.

Saturation

percentage..... Amount (% by weight) of water needed to saturate a soil.

Scaberulous..... Diminutive of scabrous.

Scabrescent..... Somewhat scabrous.

Scabrous..... Rough to the touch.

Scale ..... A thin, membranaceous, modified leaf.

Scape..... A leafless flowering stalk.

Scurfy ..... Covered with small scalelike structures.

Secund..... Turned or developed to one side.

Seed ..... A mature ovule.

Segment..... A part of a structure or organ.

Semi..... A prefix meaning "half".

Sepal..... A unit of the calyx.

Serrate..... With teeth Incline forward.

Serrulate..... Finely serrate.

Sessile..... Not stalked, as applied to leaves and flowers.

Seta ..... A bristle.

Setaceous..... Bristle-like.

Sheath..... Any tubular covering, not necessarily completely surrounding the part covered.

Shrub ..... A woody plant, usually with several main stems and mostly less than 5 m tall.

Silky ..... Covered with close-pressed, soft, straight pubescence.

Silt ..... Soil particles between 0.050.002mm In size.

Simple ..... Referring to unbranched stems or trichomes; a non-compound leaf or pistil.

Sinuate ..... Wavy margined.

Sinus. ..... The cleft or opening between two lobes.

Smooth ..... Without roughness.

Sodic ..... Soils containing sodium where saturation extract

Solitary ..... Standing alone; not clustered.

Spatulate ..... Narrowed at the base, broader and rounded at the apex.

Spherical ..... Globular; orbicular.

Spteate ..... Arranged In or resembling a spike.

Spike ..... An elongated inflorescence bearing sessile flowers.

Spikelet. ..... The basic flower cluster In grasses, usually subtended by glumes; a small or secondary spike.

Spine. ..... A leaf or part of a leaf modified Into a sharp projection.

Spinescent ..... Ending in or bearing a spine or spines.

Stamen ..... A pollen-producing organ; the male structure.

Staminate ..... Bearing stamens only (unisexual).
Stellate..... Star shaped; resembling a star.
Stellate hairs ..... Hairs with several rays or arms radiating out at the same level.
Stem. ..... The above ground axis of a plant.
Sterile ..... Sexually unproductive; not fertile.
Stigma ..... Area of the pistil receptive to pollen.
Stipulate ..... Having stipules.
Stipule ..... A leaf appendage, often attached at the point of Insertion of the leaf on the stem.
Stolon. ..... A modified, horizontal, above ground stem, usually rooting at the nodes.
Stoleniferous..... Producing stolons.
Stone..... The bony endocarp of certain fruits.
Striate.. ..... Marked with longitudinal lines or markings.
Strobllus ..... A fruiting structure bearing imbricated bracts or scales; a cone.
Style ..... The stalk-like connection between the stigma and the ovary.
Subtend ..... To be opposite to and extended from one side to the other. As to include.
Succulent..... Juicy; fleshy.
Suffrutescent..... Woody only at the base of the stem.
Symmetrical..... Divisible Into two or more like parts.

T

Tap root..... The primary root, especially when it is conspicuously larger than the other roots.
Taxon..... A group of organisms recognized as a formal unit.
Terminal.....Belonging to the end or apex.
Terrestrial.....Growing in or on the land or rooted in soil.
Texture..... The relative amounts of sand, silt and clay in soil; 12 classes, expressed in percentages.
Thorn.....A modified branch, typically sharply pointed.
Thyrse ..... A compact panicle, usually formed by a group of dichasia.
Tomentose ..... Covered with curly matted hairs.
Toxic..... Poisonous.
Trailing.....Prostrate but not rooting at the nodes.
Translucent..... Permitting the passage of light but not transparent.
Tree..... A perennial woody plant with an evident stem.
Tri.....A prefix meaning "three" or "thrice",
Trichome ..... A hairlike outgrowth of the epidermis.
Tridentate..... Three-toothed.
Trifoliolate..... Having three leaflets.

Truncate ..... Having the end square or flattened.

Tubercle ..... A small Tuber or Tuberlike Body.

Tuberculate..... Bearing Tubercles.

Tube..... The lower, usually cylindrical part of the united calyx or corolla.

Tuft.....A cluster of flexible elongated stems, attached or growing together.

Twice compound.... Referring to the primary rachis bearing secondary rachises, these in turn bearing leaflets.

Typical..... Referring to or within the limit of the ordinary variation.

U

Umbel..... An inflorescence having flowers on pedicels or having rays of about equal length, these arising from the same point at the apex of the peduncle

V

Veins..... Threads of fibrovascular tissue.

Venation..... The character of the veining.

Vernation .....The arrangement of leaves In the bud.

Villous.....Bearing fine long hairs, these not tangled or matted.

Viscid.....Sticky.

W

Weed .....An unwanted plant.

Whorl..... A group of three or more parts at one node, all at the same level, as a whorl of leaves.

Wing..... A membranous or thin expansion bordering or surrounding an organ; the two lateral petals of a papilionaceous flower.

Woolly..... Clothed with long matted hairs.

X

Xeric .....Pertaining to dry conditions or climate.

Xerophyte .....A plant of arid habitats.

Z

Zygomorphic ..... Irregular in terms of calyx or corolla, the lobes of which are different In size or shape.

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Appendix D

Contact and Web-Page Listings

Blue flax
Linum lewisii

"Contact and Web-Page Listings: Noxious Weed Control in Coal Mining Regions of the West"

Please note that the addresses, telephone numbers, and e-mail addresses that follow were current as of September 1999. If you are reading this over a computer with Internet capabilities, you should be able to click on any of the e-mail addresses listed to link directly to those addresses. State contacts are listed first, by State, followed by contacts for Indian lands. Please look to the end of the appendix for web-page information.

Alaska

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Web Pages

USDA Animal and Plant Health Inspection Service (APHIS)
Noxious Weeds Home Page
http://www.aphis.usda.gov/ppq/weeds/

Weed Science Society of America
http://www.wssa.net/

USGS Southwest Exotic Plant Mapping Program
Information on Exotic Plant Species of the Southwest
www.usgs.nau.edu/swemp/species_intro.htm

British Columbia Ministry of Agriculture and Food
Field Guide to Noxious and Other Selected Weeds of British Columbia
www.agf.gov.bc.ca/croplive/cropprot/weedguid/weedguid.htm

State Partners of the Cooperative State Research, Education, and Extension Service
www.reeusda.gov/1700/statepartners/usa.htm

University of California Statewide Integrated Pest Management
http://www.ipm.ucdavis.edu/

Colorado Department of Agriculture
Division of Plant Industry
www.ag.state.co.us/dpi

Colorado Weed Management Association
http://www.fortnet.org/CWMA/

Wyoming Weed and Pest Council
www.wyoweed.org

Utah Department of Agriculture
Plant Industry
http://www.ag.utah.gov/plantind/plantmp.htm

Utah Bureau of Land Management
Partners Against Noxious Weeds
www.blm.gov/utah/resources/weeds/weed2.htm

Invaders Database System
The University of Montana
http://invader.dbs.umt.edu/

Montana Weed Control Association
http://www.mtweed.org/

North Dakota Department of Agriculture
www.agdepartment .com/

Washington State Noxious Weed Control Board
wa.gov/agr/weedboard/index.html

King County, Washington Noxious Weed Control Program
dnr.metrokc.gov/wlr/lands/weeds/weedid.htm

Lewis County, Washington Noxious Weed Control Board
co.lewis.wa.us/Extension/Weeds/lc-nweed.htm

Appendix E

A Guide to Noxious Weeds of the Navajo Reservation

Bull thistle
Cirsium vulgare

"A Guide to Noxious Weeds of the Navajo Reservation"

The noxious weed list for Indian lands in the Four Corners region of the southwest was compiled by the Bureau of Indian Affairs. This list identifies species of invasive, exotic plants and is intended to aid in prevention and control of their infestation. Efforts to control the spread of noxious weeds are needed by land users and managers to preserve the ecological balance of native plant communities and protect the economic stability of agriculture and grazing.

This guide was arranged by the Office of Surface Mining to provide mine operators and inspectors with a reference to noxious weeds on the Navajo Reservation. Disturbed lands are especially susceptible to invasion by noxious weeds. Early detection and eradication is highly important in controlling weed establishment.

Noxious weeds are assigned a priority rating. This list includes only A and B rated species.

Priority A - Potential invaders: These weeds as yet not found on the reservation, but the potential for invasion is imminent. Emphasis will be placed on prevention, education, awareness, identification and monitoring.

Priority B - New invaders: New noxious weeds known to have invaded isolated locales on the reservation. Emphasis is placed on immediate control, prevention of seed spread and eradication. Education, awareness, identification, control and monitoring will be the priorities.

BIA NAVAJO AREA NOXIOUS WEED LIST

1998

Common Name	Priority Rating	Page
1. Bull thistle	B	E-2
2. Camel thorn	B	E-3
3. Canada thistle	B	E-4
4. Chicory	B	E-5
5. Dalmatian toadflax	A	E-6
6. Diffuse knapweed	B	E-7
7. Halogeton	B	E-8
8. Hoary cress	B	E-9
9. Jointed goatgrass	B	E-10
10. Leafy spurge	A	E-11
11. Longspine sandbur	B	E-12
12. Musk thistle	B	E-13
13. Russian knapweed	B	E-14
14. Scotch thistle	B	E-15
15. Spiny cocklebur	B	E-16
16. Spotted knapweed	B	E-17
17. Yellow starthistle	A	E-18

Bull thistle
Cirsium vulgare

Plant: biennial with short, fleshy taproot; 2-5 ft.; many spreading branches; stems are sparsely hairy and spiny winged; Sunflower family; similar to Canada thistle*

Leaves: lobed, ending in long, sharp spines; hairy and prickly on upper side and cottony underneath; rosette forms in first year of growth

Flowers: dark purple; 1.5-2 inches wide; more or less clustered at branch ends; bracts surrounding flower heads are narrow, spine-tipped and become longer and narrower from outer to inner

Habitat: invades pastures, roadsides and disturbed areas

* Differences are that Canada thistle does not have prickly hairs on surface of leaves, has smaller flowers and creeping roots

Camel thorn
*Alhagi camelorum**

Plant: perennial shrub; 1 ½ - 4 ft.; deep, creeping roots; stem is spiny with sparse leaves; Pea family

Leaves: wedge-shaped; 1/4 - 1 1/4 inches long and 1/8 - ½ inch wide (lower leaves larger than upper); thick textured; hairs on underside

Flowers: pinkish-purple to maroon; small (1 cm. long); 2-7 occurring on spine-tipped branchlets in upper portion of plant

Habitat: saline meadows, sandbars, playas, riverbanks, irrigation canals and croplands

*Also called *Alhagi pseudalhagi* or *Alhagi maurorum*

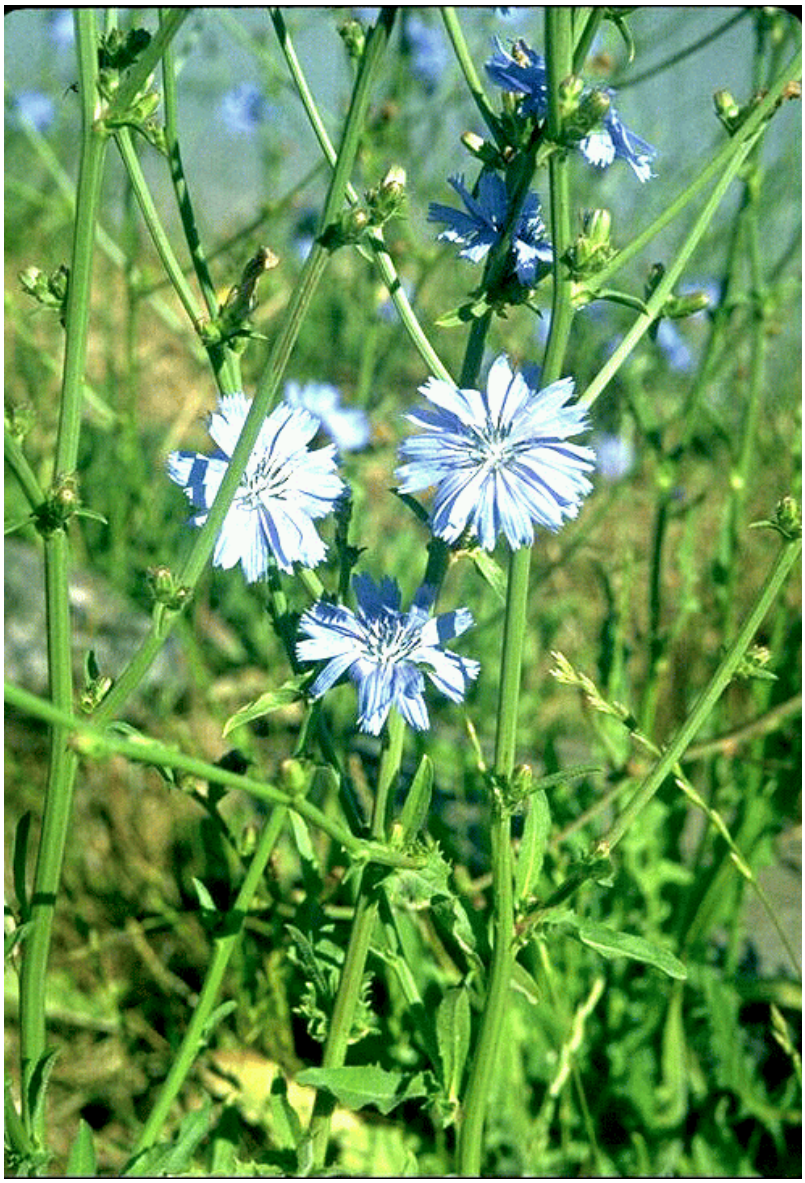
Canada thistle
Cirsium arvense

Plant: creeping root perennial; 1-4 ft.; stems are hollow and branched above; Sunflower family

Leaves: stalkless; dark green; divided into spiny-tipped irregular lobes

Flowers: purple to pink to white; ½-3/4 inch in diameter (small in comparison to other thistles); bracts surrounding heads are spineless

Habitat: invades cultivated fields, riparian areas, pastures, rangelands, forests, roadsides and disturbed areas



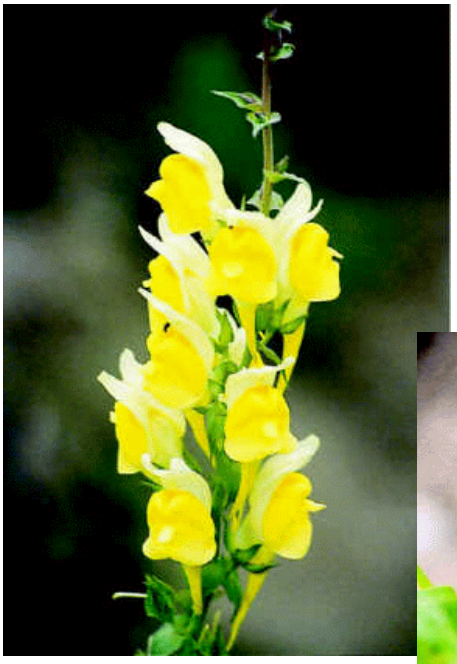
Chicory
Cichorium intybus

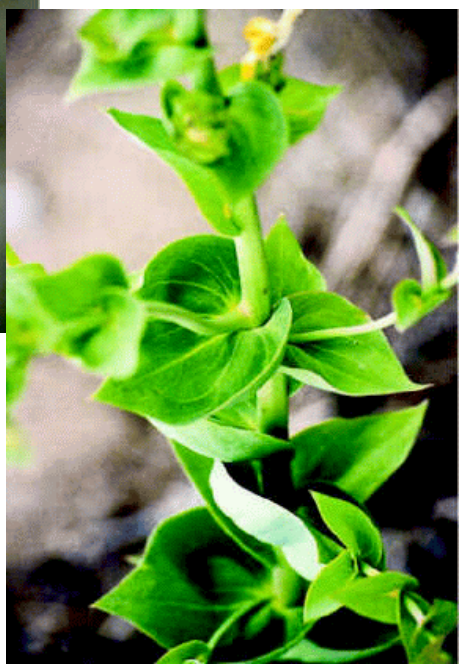
Plant: perennial; 1-6 ft.; spreading branches; deeply taprooted; contains milky juice; Sunflower family

Leaves: rough textured; leaves at base of plant are in a rosette, toothed to divided and 2-10 inches long; upper leaves are smaller, unlobed and clasp the stem

Flower: bright blue to purple, occasionally white; up to 1 ½ in. diameter; 1-3 flower heads growing out of leaf axils

Habitat: roadsides and disturbed areas





Dalmatian toadflax
*Linaria dalmatica**

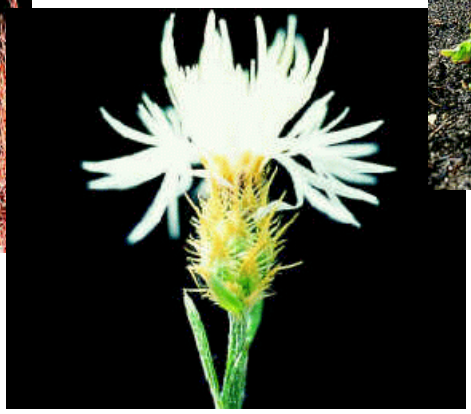
Plant: creeping perennial; 2-4 feet; deep rooted; Snapdragon family

Leaves: pale green, waxy, clasping stem; heart-shaped with pointed tip

Flower: bright yellow with orange centers; 1-2 inches long; 2-lipped with a long spur

Habitat: invades rangelands and roadsides; especially adapted to arid sites

* Also called *Linaria genistifolia*



Diffuse knapweed
Centaurea diffusa

Plant: annual to short-lived perennial; 1-2 feet; single, much-branched stem; Sunflower family

Leaves: grayish-green, hairy; lower leaves divided; bitter to taste; basal rosette of leaves in young plant

Flower: white, occasionally purple; 1-1.5 inch diameter; bracts around flower head with small, sharp, rigid spines

Habitat: roadsides, riparian areas, overgrazed rangelands; rapidly invades disturbed areas and highly competitive on dry sites

Halogeton
Halogeton glomeratus

Plant: annual; 2-18 inches; red stems branch at base, spreading then becoming erect; Goosefoot family

Leaves: small, fleshy, nearly tubular with needle-like spine at tip

Flowers: green; inconspicuous; growing in leaf axils in the fall

Habitat: invades disturbed or overgrazed lands; especially adapted to alkaline soils in semi-arid environments

Hoary cress
Cardaria draba

Plant: perennial with creeping roots; up to 2 ft.; plant has flat, white-topped appearance; Mustard family

Leaves: oval-shaped with smooth to toothed margins; ½ - 2 inches long; blue-green color; lower leaves are stalked and hairy, upper ones have two lobes that clasp stem

Flowers: 4 white petals; 1/8 inch diameter; numerous

Fruit: heart-shaped seed pods contain 2 reddish-brown seeds separated by a partition

Habitat: alkaline, disturbed soils in waste places, cultivated fields and pastures; emerges very early in spring and is highly competitive once establish

Jointed goatgrass
Aegilops cylindrica

Plant: winter annual grass; 15-30 inches; erect stems that branch at the base

Leaves: blades are 1/4 - 1/8 inch wide

Flowers: flowering spike is cylindrical and jointed into 2-12 segments that are each about ½ inch long

Habitat: wheat fields, pastures, roadsides and waste areas

Leafy spurge
Euphorbia esula

Plant: perennial; up to 3 ft. tall; persistent, creeping roots; all parts of plant contain milky juice that irritates skin; Spurge family

Leaves: narrow; 1-4 inches long; thickly clustered on stem

Flowers: yellow-green; inflorescence above a pair of heart-shaped, yellow-green bracts

Habitat: invades pastures and cultivated areas

Longspine sandbur
Cenchrus longispinus

Plant: annual grass; 8 in. to 3 ft.; usually spreading on ground in dense mat; flattened stems

Leaves: blades are 2-6 in. long and 1/4 in. wide, flat and rough textured; sheaths around stem have hairy margins

Flowers: spikes are 1-3 inches long with clusters of 10-30 burs; burs have stiff, barbed spines and are about 1/4 inch diameter

Habitat: invades cultivated fields, pastures and waste areas; favors sandy or gravelly soils

Musk thistle
Carduus nutans

Plant: biennial or winter annual; 2-6 ft; Sunflower family

Leaves: 3-6 inches long; dark green with light green midrib; waxy; deeply lobed with spiny margins; leaves extend or clasp down stem; first year's growth is a large, compact rosette

Flowers: deep rose, violet or purple; 1.5-3 inches in diameter; solitary and nodding; head surrounded by broad, spine-tipped bracts

Habitat: invades pastures, rangelands, waste areas, stream and ditch banks; prefers moist, bottom land soil but will grow on drier uplands as well

Russian knapweed
Centaurea repens

Plant: perennial with creeping, often black, roots; 1-3 ft.; stems are erect and branched; young stems covered in soft, gray hairs; Sunflower family

Leaves: lower leaves form a rosette, are deeply lobed and 2-4 inches long; upper become progressively smaller towards top of plant and are narrow with broken edges; both types are covered with a fine hair

Flowers: pink to lavender to white; 1/4-1/2 inch in diameter; heads are cone-shaped, thistle-like and solitary at tip of leafy branches; bracts surrounding flower heads are rounded with papery margins

Habitat: invades cultivated fields, pastures, roadsides, fence rows and waste places

Scotch thistle
Onopordum acanthium

Plant: biennial; 3-12 ft.; much branched; covered with dense, white hairs; stem is broad, spiny and winged; Sunflower family

Leaves: lower leaves are large (up to 2 ft. long and 1 ft. wide), lobed, densely covered with white hairs, and margins are wavy and spiny; leaves on stem are similar but smaller

Flowers: purple; 1-2 inch diameter; no rays; at ends of branches and in axils of leaves; heads nearly spherical; flower heads surrounded by overlapping, narrow, spine-tipped bracts

Habitat: gravelly soils, waste places, roadsides

Spiny cocklebur
Xanthium spinosum

Plant: annual; up to 2 ft.; stiff, yellow, 3-forked spines 1-2 inches long located where leaf joins the stem; Sunflower family

Leaves: narrow; 1-3 inches long with 2 lobes or teeth at base; densely covered with short white hairs below, white veined above

Flowers: greenish, inconspicuous; 2 types: male, sterile flowers clustered at top of plant, female flowers below the male flowers and developing into the fruits

Fruits: pale yellow, egg-shaped burs with hooked bristles and short beak at tip

Habitat: meadows, roadsides, disturbed sites, dry areas

Spotted knapweed
Centaurea maculosa

Plant: biennial to short-lived perennial; 1-4 ft.; stout taproot; erect stem with slender branches in upper portion of plant; Sunflower family

Leaves: leaves at base 4-8 inches long, hairy and deeply lobed; leaves on stem are smaller and finely divided

Flowers: pinkish-purple; 1 inch in diameter; flower heads are solitary, growing at ends of branches; bracts surrounding the flower heads are stiff and tipped with a black, comb-like fringe (giving plant a “spotted” appearance)

Habitat: dry meadows, rangelands, pastures, rocky hills, roadsides and sandy or gravelly flood plains; well-drained, light textured soils

Yellow starthistle
Centaurea solstitialis

Plant: annual; 2-3 ft.; heavily branched, winged stems covered with cottony hair; Sunflower family

Leaves: deeply lobed at base; unlobed and sharply pointed on upper stems

Flowers: yellow; growing singly at ends of branches; sharp thorns up to 3/4 inch long surround flower heads

Habitat: various soil types, usually on roadsides and waste areas

Plant images provided by:

- British Columbia Ministry of Agriculture and Food
- University of California Statewide Integrated Pest Management Project
- Brousseau California Flora Pictures
  Berkeley Digital Library Project
- S.W. School of Botanical Medicine; Bisbee, AZ
- University of Pennsylvania School of Veterinary Medicine

Appendix F

A Guide to Noxious Weeds of the Centralia Mine, Washington State

Annual bugloss
Anchusa arvensis

The noxious weed list for Centralia coal mine is comprised of the Thurston and Lewis County weed lists. These lists were compiled by the Thurston County Noxious Weed Control Agency and the Lewis County Noxious Weed Board and identify species of invasive, exotic plants. Efforts to control the spread of noxious weeds are needed by land users and managers to preserve the ecological balance of native plant communities and protect agricultural lands and natural resources.

This guide was arranged by the Office of Surface Mining to provide mine operators and inspectors with a reference to noxious weeds in the area. Disturbed lands are especially susceptible to invasion by noxious weeds and early detection and eradication is highly important in controlling weed establishment.

Class A weeds are non-native species with a limited distribution in Washington. Preventing new infestations and eradicating existing infestations is the highest priority.

Class B weeds are non-native species that are presently limited to portions of the State and are designated for control in regions where they are not yet widespread. Preventing infestations in these areas is a high priority. In regions where these species are already abundant, control is decided at the local level, with containment a primary goal.

Class C weeds are other non-native weeds found in Washington. Many of these species are widespread in the State.

LEWIS AND THURSTON COUNTIES
NOXIOUS WEED LIST
1998

Common Name	Scientific Name	Class	Page*
Absinth wormwood	*Artemisia absinthium*	C	
Annual bugloss	*Anchusa arvensus*	B	F-4
Austrian fieldcress	*Rorippa austriaca*	B	
Babysbreath	*Gypsophila paniculata*	C	
Bitter nightshade	*Solanum dulcamara*	C	
Blackgrass	*Alopecurus myosuroides*	B	
Black henbane	*Hyoscyamus niger*	C	
Bighead knapweed	*Centaurea macrocephala*	A	F-5
Black knapweed	*Centaurea nigra*	B	F-6
Blueweed	*Echium vulgare*	B	F-7
Brazilian elodea	*Egeria densa*	B	F-8
Brown knapweed	*Centaurea jacea*	B	F-9
Buffalobur	*Solanum rostratum*	A	F-10
Bull thistle	*Cirsium vulgare*	C	
Camelthorn	*Alhagi maurorum*	B	
Canada thistle	*Cirsium arvense*	C	F-11

* Descriptions and pictures are provided for those species that receive highest priority in educational and surveying activities.

Common Name	Scientific Name	Class	Page
Cereal rye	*Secale cereale*	C	
Clary sage	*Salvia sclarea*	A	F-12
Common bugloss	*Anchusa officinalis*	B	F-13
Common cordgrass	*Spartina anglica*	B	
Common crupina	*Crupina vulgaris*	A	
Common mullein	*Verbascum thapsus*	C	
Common St. Johnswort	*Hypericum perforatum*	C	
Common tansy	*Tanacetum vulgare*	C	
Dalmatian toadflax	*Linaria dalmatica ssp. dalmatica*	B	F-14
Diffuse knapweed	*Centaurea diffusa*	B	F-15
Dwarf snapdragon	*Chaenorrhinum minus*	C	
Dyers woad	*Isatis tinctori*	A	
Eurasian watermilfoil	*Myriophyllum spicatum*	B	F-16
Fanwort	*Cabomba caroliniana*	B	
Field bindweed	*Convolvulus arvensis*	C	
Garden loosestrife	*Lysimachia vulgaris*	B	F-17
Garden rocket	*Eruca visicaria ssp.sativa*	C	
Giant hogweed	*Heracleum mantegazzianum*	A	F-18
Gorse	*Ulex europaeus*	B	F-19
Hairy whitetop	*Cardaria pubescens*	C	
Hawkweed oxtongue	*Picris hieracioides*	B	
Hedgeparsley	*Torilis arvensis*	B	F-20
Herb-Robert	*Geranium robertianum*	A	F-21
Hoary cress	*Cardaria draba*	C	
Houndstongue	*Cynoglossum officinale*	C	
Hydrilla	*Hydrilla verticillata*	A	
Hybrid deadnettle	*Lamium hybridum*	B	
Indigobush	*Amorpha fruticosa*	B	
Italian thistle	*Carduus pycnocephalus*	A	F-22
Japanese knotweed	*Polygonum cuspidatum*	C	
Johnsongrass	*Sorghum halepense*	A	
Jointed goatgrass	*Aegilops cylindrica*	C	
Kochia	*Kochia scoparia*	B	
Lawnweed	*Soliva sessilis*	A	F-23
Leafy spurge	*Euphobia esula*	B	F-24
Lepyrodiclis	*Lepyrodiclis holosteoides*	B	
Longspine sandbur	*Cenchrus longispinus*	B	
Meadow clary	*Salvia pratensis*	A	
Meadow knapweed	*Centaurea jacea x nigra*	B	F-25
Mediterranean sage	*Salvia aethopis*	A	
Milk thistle	*Silybum marianum*	A	F-26
Mouseear hawkweed	*Hieracium pilosella*	A	F-27
Musk thistle	*Carduus nutans*	B	
Orange hawkweed	*Hieracium aurantiacum*	B	F-28

Common Name	Scientific Name	Class	Page
Parrotfeather	*Myriophyllum aquaticum*	B	F-29
Peganum	*Peganum harmala*	A	
Perennial pepperweed	*Lepidium latifolium*	B	
Perennial sowthistle	*Sonchus arvensis ssp.arvensis*	B	F-30
Plumeless thistle	*Carduus acanthoides*	B	
Poison hemlock	*Conium maculatum*	C	F-31
Polar hawkweed	*Hieracium atratum*	B	
Purple loosestrife	*Lythrum salicaria*	B	F-32
Purple starthistle	*Centaurea calcitrapa*	A	
Reed canarygrass	*Phalaris arundinacea*	C	
Rush skeletonweed	*Chondrilla juncea*	B	F-33
Russian knapweed	*Acroptilon repens*	B	
Saltcedar	*Tamarix* species	C	
Salt meadow cordgrass	*Spartina patens*	A	
Scentless mayweed	*Matricaria perforata*	C	
Scotch thistle	*Onopordum acanthium*	B	F-34
Silverleaf nightshade	*Solanum elaeagnifolium*	A	
Slenderflower thistle	*Carduus tenuiflorus*	A	F-35
Smooth cordgrass	*Spartina alterniflora*	B	
Smooth hawkweed	*Hieracium laevigatum*	B	
Smoothseed alfalfa dodder	*Cuscuta approximata*	C	
Spanish broom	*Spartium junceum*	A	F-36
Spikeweed	*Hemizonia pungens*	C	
Spiny cocklebur	*Xanthium spinosum*	C	
Spotted knapweed	*Centaurea biebersteinii*	B	F-37
Swainson pea	*Sphaerophysa salsula*	B	
Syrian bean-caper	*Zygophyllum fabago*	A	
Tansy ragwort	*Senecio jacobaea*	B	F-38
Texas blueweed	*Helianthus ciliaris*	A	
Unicorn-plant	*Proboscidea louisianica*	A	
Velvetleaf	*Abutilon theophrasti*	A	F-39
Venice mallow	Hibiscus trionum	A	
Vochin knapweed	*Centaurea nigrescens*	A	
Wand loosestrife	*Lythrum virgatum*	B	F-40
White bryony	*Bryonia alba*	B	
White cockle	*Silene latifolia ssp.alba*	C	
Wild carrot	*Daucus carota*	C	
Wild chervil	*Anthricus sylvestris*	C	
Wild four o’ clock	*Mirabilis nyctaginea*	A	
Yellow devil hawkweed	*Hieracium floribundum*	A	F-41
Yellow hawkweed	*Hieracium caespitosum*	B	
Yellow nutsedge	*Cyperus esculentus*	B	F-42
Yellow starthistle	*Centaurea solstitialis*	B	F-43
Yellow toadflax	*Linaria vulgaris*	C	

Annual bugloss
Anchusa arvensis

Plant: annual; 6-18 inches in height; stems are rough hairy; Borage family

Flower: 3-4 inches in diameter, bright blue to purple with white or yellow “eye” in center; 5 petals

Leaves: narrow, 12-16 inches long; toothed and wavy margins; upper leaves clasp the stem

Habitat: open forest, fields, roadsides, disturbed areas

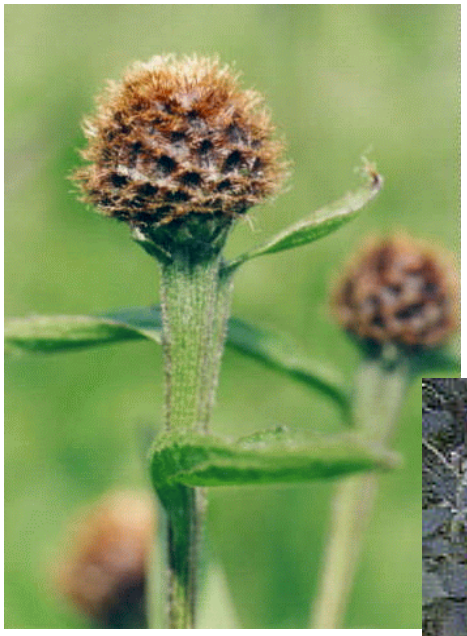
Bighead knapweed
Centaurea macrocephala

Plant: perennial; up to 4 ft. tall; hearty stems; Sunflower family

Leaves: coarse textured

Flowers: yellow; 3-4 inch diameter; globe-shaped

Habitat: prefers well-drained soils



Black knapweed
Centaurea nigra

Plant: perennial; 6-36 inches; dull green in color, covered with small hairs; branched in upper part of plant; Sunflower family

Leaves: variable; upper leaves are narrow and not lobed, lower leaves are lobed or have coarsely toothed margins

Flower: purple tubular flowers, no ray flowers; black fringes on bracts around flower head

Habitat: invades pastures, roadsides

Blueweed
Echium vulgare

Plant: biennial to short-lived perennial; 2-3 ft; stems and leaves covered with stiff hairs; stem often has red spots; Borage family

Leaves: 4-5 in. long

Flowers: turn from rose to bright blue; grow on upper side of short, curved stem

Habitat: invades rangelands, pastures and roadsides; grows on coarse, sandy to gravelly

soil

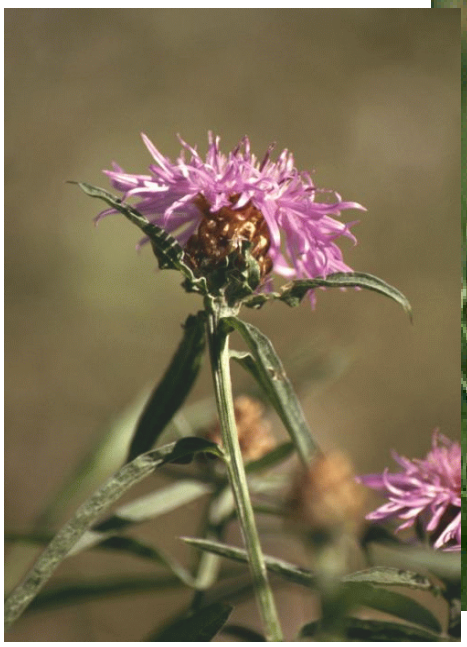
Brazilian elodea
Egeria densa

Plant: stems 1-2 ft. or more; fern-like, bright green foliage; forms dense mats

Leaves: slender, strap-shaped; 1 in. long, 1/4 inch wide; fine saw-tooth margins

Flowers: 3/4 inch diameter; white; 3 petals

Habitat: aquatic, submerged



Brown knapweed
Centaurea jacea

Plant: perennial; similar to Spotted knapweed but more robust; Sunflower family

Leaves: undivided, irregularly toothed, somewhat hairy

Flowers: pink-purple; bracts surrounding flower heads are light brown with the upper half of each bract expanded and irregularly divided (not fringed)

Habitat: pastures, roadsides, wasteplaces

Buffalobur
Solanum rostratum

Plant: annual shrub; up to 2 ft. high; stems hairy and covered with numerous yellow spines about 1 cm. long; Nightshade family

Leaves: 2-5 inches long; dark green; irreg-ularily lobed; star-shaped hairs on the upper surface, prickles on veins and leaf stalks

Flowers: yellow, 5 petals, 1 inch wide; one stamen longer than the others and curves inwards

Fruit: berry about 1 cm. in diameter covered in dense spines

Habitat: disturbed wastelands and prairies; most common on sandy soils but will grow on most soils; drought tolerant

Canada thistle
Cirsium arvense

Plant: creeping root perennial; 1-4 ft.; stems are hollow and branched above; Sunflower family

Leaves: stalkless; dark green; divided into spiny-tipped irregular lobes

Flowers: purple to pink to white; ½-3/4 inch in diameter (small in comparison to other thistles); bracts surrounding heads are spineless

Habitat: invades cultivated fields, riparian areas, pastures, rangelands, forests, roadsides and disturbed areas

Clary sage
Salvia sclarea

Plant: strong-smelling biennial or perennial; 2-3 ft.; sqare stem; Mint family

Leaves: broad heart-shaped; irregularily toothed; covered with velvety hairs; arranged in pairs on stem

Flowers: lilac or pale blue to white; about 1 inch long; 2-lipped; inflorescence a loose spike; produces flowers in second year of growth

Habitat: rocky and grassy areas, roadsides

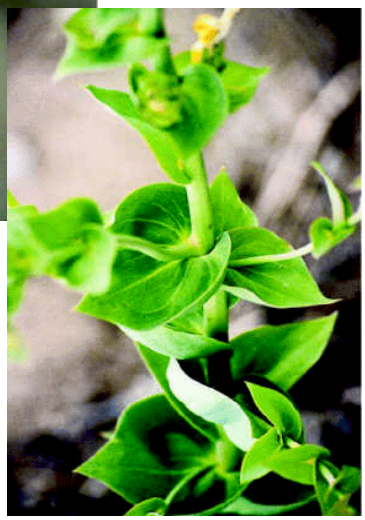
Common bugloss
Anchusa officinalis

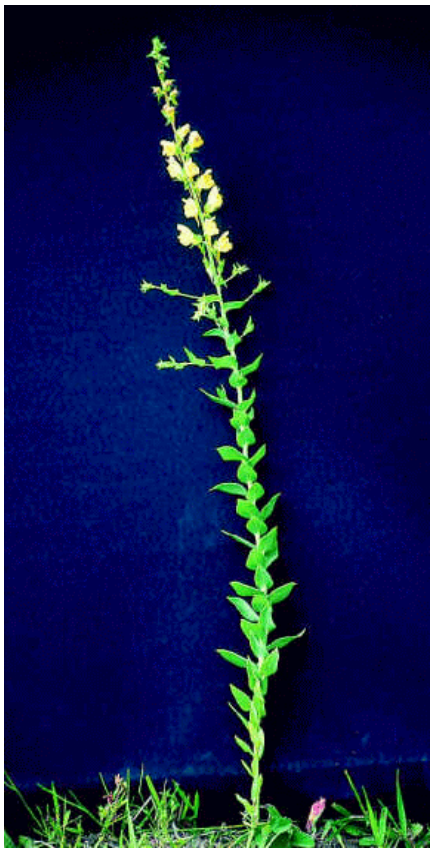
Plant: biennial or perennial; up to 3 ft.; plant covered with stiff hairs; Borage family

Leaves: 2-5 inches long; narrow with a pronounced midrib; upper leaves clasp stem

Flowers: violet with white stars in center; 3-6 in. diameter; funnel-shaped; flowers on short stalks and in a dense, one-sided inflorescence

Habitat: croplands, fields; prefers nutrient-rich sandy and gravelly soils





Dalmatian toadflax
*Linaria dalmatica ssp. dalmatica**

Plant: creeping perennial; 2-4 feet; deep-rooted; Snapdragon family

Leaves: pale green, waxy, clasping stem; heart-shaped with pointed tip

Flower: bright yellow with orange centers; 1-2 inches long; 2-lipped with a long spur

Habitat: invades rangelands and roadsides; especially adapted to arid sites

* Also called *Linaria genistifolia*

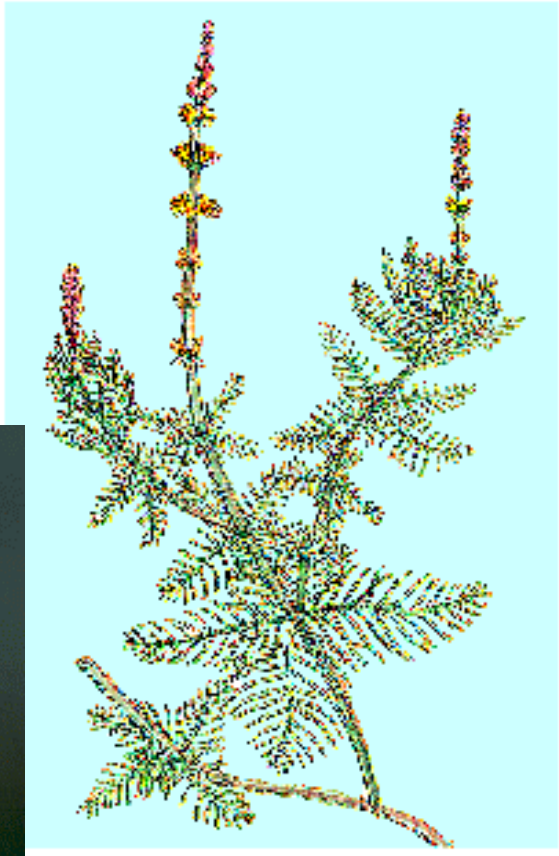
Diffuse knapweed
Centaurea diffusa

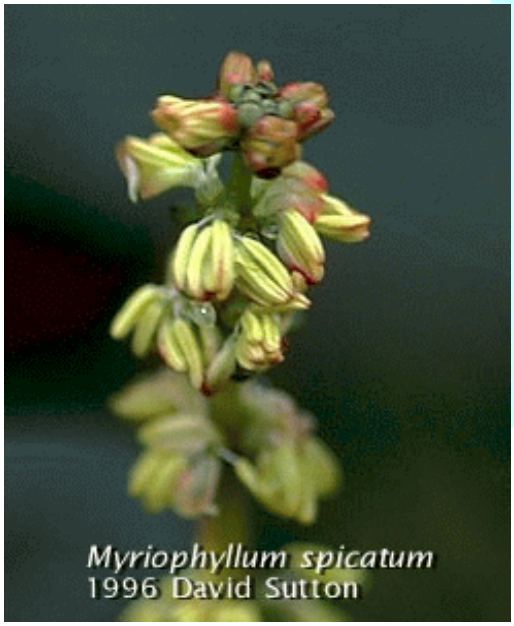
Plant: annual to short-lived perennial; 1-2 feet; single, much-branched stem; Sunflower family

Leaves: grayish-green, hairy; lower leaves divided; bitter to taste; basal rosette of leaves in young plant

Flower: white, occasionally purple; 1-1.5 inch diameter; bracts around flowerhead with small, sharp, rigid spines

Habitat: roadsides, riparian areas, overgrazed rangelands; rapidly invades disturbed areas and highly competetive on dry sites





Eurasian watermilfoil
Myriophyllum spicatum

Plant: aquatic, submerged perennial; stem is reddish-brown to whitish-pink, 6-9 ft. and branched near the water surface; growing stem tip is tassle-like and stem width almost doubles below inflorescence

Leaves: divided, feather-like, in whorls of four leaves around stem

Flower: small, pinkish; above water on a spike 2-8 inches long

Habitat: occurs mainly in nutrient-rich (eutrophic) lakes and waterways

Garden loosestrife
Lysimachia vulgaris

Plant: rhizomatous perennial; up to 3 ft. or more

Leaves: 3-5 inches long; softly hairy; dotted with black and orange glands; opposite or whorled arrangement on stem;

Flowers: yellow, 5 petals; in cluster at top of plant

Habitat: invades wetlands/moist areas

Giant hogweed
Heracleum mantegazzianum

Plant: biennial or perennial; up to 15 ft.; stems hollow; sap causes skin irritation; Parsley family

Leaves: enormous; compound with three leaflets, the lower leaflets up to 8 ft. long

Flower: small flowers in umbrella-shaped inflorescence

Habitat: uncultivated or waste lands, along roadsides and streams

Gorse
Ulex europaeus

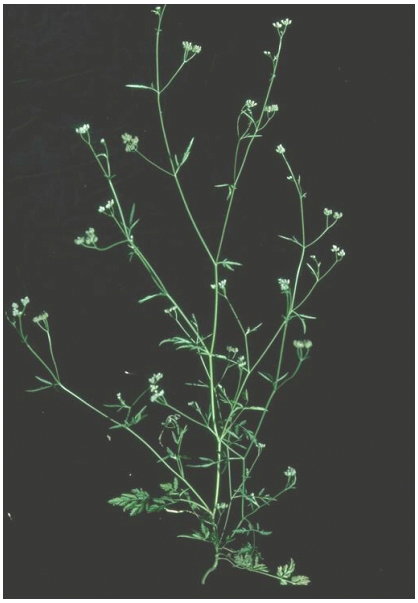
Plant: spiny, perennial shrub; grows up to 6 ft. tall; Pea family

Leaves: small leaves terminate in rigid spines

Flower: bright yellow; surrounded by velvety calyx

Fruit: black, hairy seedpods

Habitat: has invaded along coasts of the Pacific Ocean



Hedgeparsley
Torilis arvensis

Plant: annual; taproot; hairy or bristly foliage; Parsley family

Leaves: blades 2-5 inches long; triangular-shaped; deeply dissected with narrow segments

Flowers: white or reddish; small flowers in umbrella-shaped inflorescense; petals wide with narrow tips

Fruits: oblong to ovate; slightly compressed; prickly

Habitat: disturbed places

Herb-Robert
Geranium robertianum

Plant: annual; sprawling stem is about 15 inches long, reddish and hairy; Geranium family

Leaves: deeply lobed; red margins; 2-3 inches across; strong, unpleasant odor

Flowers: ½ inch diameter; 5 petals; purplish-pink color; blooms in pairs

Fruit: seed pods that burst open when ripe

Habitat: rocky sites, walls, banks and shaded areas

Italian thistle
Carduus pycnocephalus

Plant: annual or biennial; 1-4 ft.; stems more or less wooly with spiny wings; Sunflower family

Leaves: deeply lobed with spines; undersurface thinly wooly

Flowers: purplish or pinkish; in cylindric heads that are either single or in clusters of 2 to 5; bracts around heads are hairy

Habitat: invades roadsides and waste areas, can be a major problem on hill pasture land

Lawnweed
Soliva sessilis

Plant: low-growing annual; 2 inches in height; individual plants about 6 inches in diameter; as plants spread, they cover the ground like a carpet

Leaves: deeply dissected, giving plant a feathery appearance; foliage covered with fine hairs

Flowers: yellow, inconspicuous; growing in axils of leaves and with small spines

Fruits: seeds enclosed in a small, flat, spined bur

Habitat: fields and parks; plant emerges in fall and matures in early spring, with vegetative part of plant drying up by May

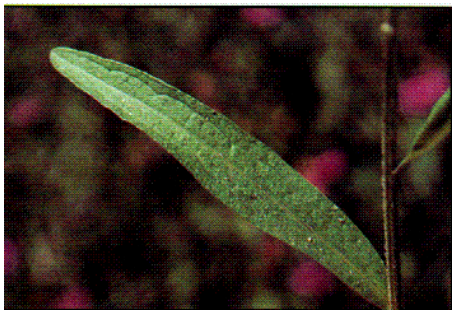
Leafy spurge
Euphorbia esula

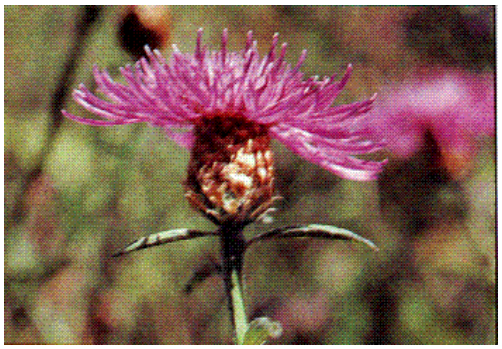
Plant: perennial; up to 3 ft. tall; persistent, creeping roots; all parts of plant contain milky juice that irritates skin; Spurge family

Leaves: narrow; 1-4 inches long; thickly clustered on stem

Flowers: yellow-green; inflorescence above a pair of heart-shaped, yellow-green bracts

Habitat: invades pastures and cultivated areas





Meadow knapweed
*Centaurea pratensis**

Plant: perennial; up to 3.5 ft. and with many branches

Leaves: lower leaves coarsely lobed and with long stalks; upper leaves smaller, not lobed and without (or with short) stalks

Flowers: large pink to purplish heads; growing at tips of branches; bracts around flower heads light to dark brown and deeply fringed

Habitat: invades roadsides, waste areas, fields and pastures

* Considered to be a hybrid between brown knapweed *(Centaurea jacea)* and black knapweed *(Centaurea nigra*)

Milk thistle
Silybum marianum

Plant: biennial or winter annual; stout, ridged stems up to 6 ft. tall; Sunflower family

Leaves: can reach 1 ft. or more in length; broad, lobed and with spiny margins; clasps the stem with ear-like lobes at the base; white marbling along veins

Flowers: red-purple; leathery spine-tipped bracts around flower head

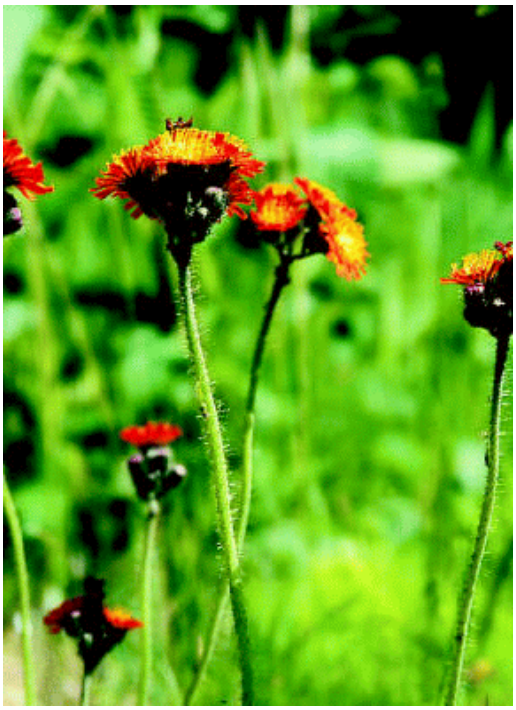
Mouseear hawkweed
Hieracium pilosella

Plant: creeping runners; milky sap

Leaves: small rosette of hairy, undivided leaves

Flowers: bright yellow, 1 inch diameter; one flower per leafless stem

Habitat: dry meadows



Orange hawkweed
Hieracium aurantiacum

Plant: perennial; 1 ft. tall; above ground runners; contains milky juice; flowering stalk covered with stiff, black, glandular hairs; Sunflower family

Leaves: mostly at base of plant, with one or two small leaves on stem

Flowers: bright orange-red with notched tips

Parrotfeather
Myriophyllum aquaticum

Plant: aquatic; stem grows to about 5 ft. long, trails along the ground or water surface and becomes erect at the ends; tip can grow up to 1 ft. above water

Leaves: oblong, deeply cut, feathery looking; 2 types: submersed and emergent; the emergent leaves are 1-2 inches long, very stiff and bright green (darker than the submersed leaves); the submersed leaves are 0.5-1.5 inches long and limp

Flowers: white, inconspicuous, 1/16 inch; grow in axils of leaves

Habitat: freshwater lakes, streams, ponds; also invades drainage ditches; tends to colonize in slow-moving waters

Perennial sowthistle
Sonchus arvensis ssp. arvensis

Plant: perennial; 2-4 ft.; creeping roots; stems branch near the top; plant contains milky juice; Sunflower family

Leaves: clasp stem; weak prickles on margins; vary from deeply toothed to unlobed; upper leaves much smaller than basal ones

Flowers: yellow, up to 2 inch diameter; bracts surrounding flower head usually covered with gland-tipped hairs

Habitat: invades cultivated crops, ditchbanks and fertile waste areas where there is adequate water available

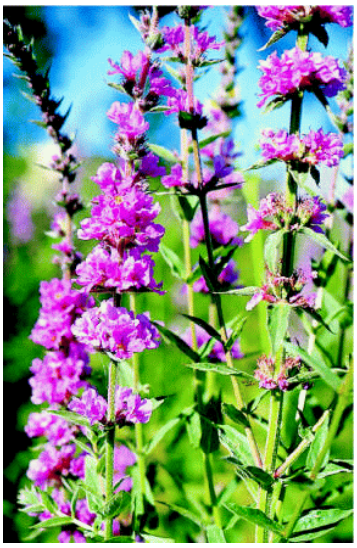
Poison-hemlock
Conium maculatum

Plant: perennial; 2-6 ft.; hollow, purple-spotted stem; white, fleshy taproot; entire plant has a disagreeable odor; Parsley family

Leaves: very divided; parsley-like

Flowers: small, white; inflorescence of flat-topped clusters

Habitat: roadsides, waste places



Purple loosestrife
Lythrum salicaria

Plant: perennial; 3-9 ft.; 4-sided stem; Loosestrife family

Leaves: opposite or whorled arrangement on stem

Flowers: rose-purple; 5-7 petals; inflorescence a dense terminal spike

Habitat: wetlands; invades streambanks and shorelines of shallow ponds; infestations impede waterflow in canals and ditches

Wand loosestrife
Lythrum virgatum

Plant: perennial; 2-3 feet; virtually indistinguishable from purple loosestrife, although smaller

Rush skeletonweed
Chondrilla juncea

Plant: perennial; 1-4 ft.; much branched, wiry stems covered with stiff, reddish-brown, downwardly bent hairs at base; stems contain milky juice; Sunflower family

Leaves: very small and narrow on upper plant, giving a “skeleton-like” appearance; sharply-toothed and in a rosette at base that withers as plant developes

Flowers: 3/4 inch diameter; yellow

Habitat: establishes in well-drained, often disturbed, soils along roadsides, in rangelands, grain fields and pastures

Scotch thistle
Onopordum acanthium

Plant: biennial; 3-12 ft.; much branched; covered with dense, white hairs; stem is broad, spiny and winged; Sunflower family

Leaves: lower leaves are large (up to 2 ft. long and 1 ft. wide), lobed, densely covered with white hairs, and margins are wavy and spiny; leaves on stem are similar but smaller

Flowers: purple; 1-2 inch diameter; no rays; at ends of branches and in axils of leaves; heads nearly spherical; flower heads surrounded by overlapping, narrow, spine-tipped bracts

Habitat: gravelly soils, waste places, road-sides

Slenderflower thistle
Carduus tenuiflorus

Plant: annual or biennial; 1-4 ft.; stems with spiny wings; closely resembles Italian thistle; Sunflower family

Leaves: deeply lobed with spines; undersurface thinly wooly

Flowers: purplish or pinkish; in cylindric heads that are in clusters of more than 5; bracts around heads are *not* hairy

Spanish broom
Spartium junceum

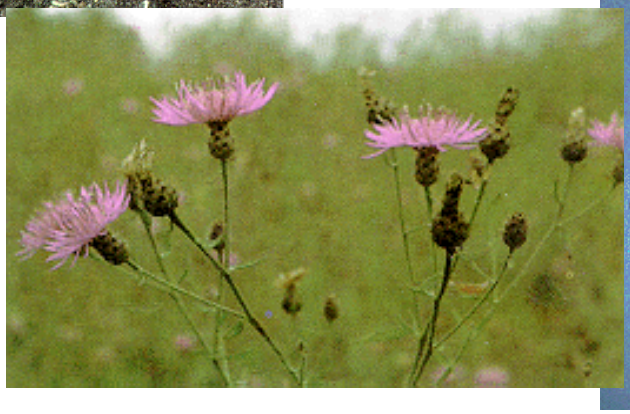
Plant: perennial shrub; grows up to 9 ft.; long, slender, leafless or few-leaved branches

Leaves: ½-1 inch long; unlobed; oblong

Flowers: bright yellow; about 1 inch long; fragrant; growing in loose, terminal inflorescences (unlike Scotch broom, in which flowers are solitary and grow in the axils of leaves)

Fruits: pods are 2-4 inches, compressed and many-seeded

Habitat: dry slopes, open woodlands, road-sides



Spotted knapweed
*Centaurea biebersteinii**

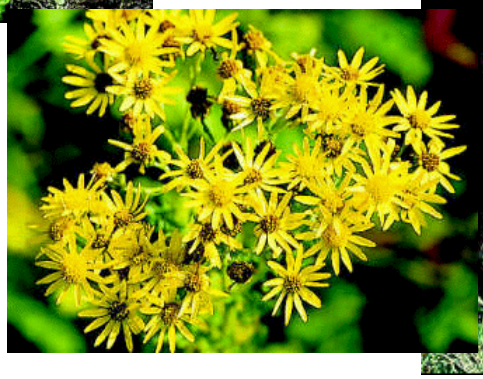
Plant: biennial to short-lived perennial; 1-4 ft.; stout taproot; erect stem with slender branches in upper portion of plant; Sunflower family

Leaves: pale green; lower leaves 4-8 inches long, divided and with a rough surface; upper leaves linear

Flowers: pink-purple; 1 inch diameter; flower heads are solitary, growing at tips of branches; heads surrounded by stiff, black-tipped bracts (giving plant a "spotted" appearance)

Habitat: invades dry meadows, pasure and rangelands, roadsides and gravelly floodplains; prefers well-drained, sandy soils

* Also called *Centaurea maculosa*



Tansy ragwort
Senecio jacobaea

Plant: biennial or short-lived perennial from taproot; 1-6 ft.; foliage covered in cobwebby hairs in early stages of growth; Sunflower family

Leaves: 2-8 inches long; deeply cut into irregular segments; terminal lobe generally longer than lateral ones

Flowers: yellow; numerous heads in a flat-topped cluster

Habitat: invades range and pasture land

Velvetleaf
Abutilon theophrasti

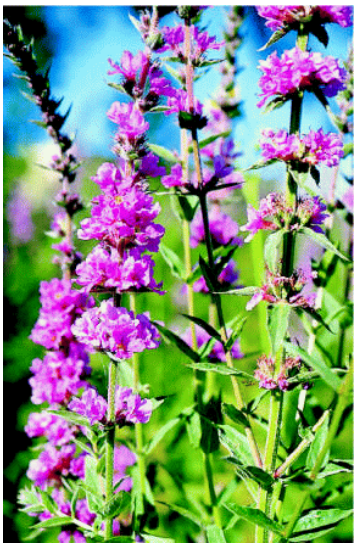
Plant: annual; 2-7 ft.; completely covered with soft hairs; Mallow family

Leaves: heart-shaped; 5 inches or more in width

Flowers: solitary in leaf axils; 5 yellow-orange petals; stamens fused into a tube

Fruits: rounded with 9 to 15 segments arranged in a disk

Habitat: on rich soils in cultivated fields,gardens, fence rows and waste areas



Wand loosestrife
Lythrum virgatum

Plant: perennial; 2-3 feet; virtually indistinguishable from purple loosestrife, although smaller

No picture available for yellow devil hawkweed. Please see orange hawkweed, which looks very similar, except has orange flowers instead of yellow.

Yellow devil hawkweed
Hieracium floribundum

Plant: perennial; above-ground runners; contains milky juice; Sunflower family

Leaves: mostly at base of plant with a few small leaves on erect stem

Flowers: yellow; more than one flower head per stem

Habitat: forest clearings, meadows, pastures, and disturbed areas

Yellow nutsedge
Cyperus esculentus

Plant: grass-like perennial; 6-30 inches; 3-sided stem is leafless except for leaf-like bracts that radiate out from just below the umbrella-like flower cluster; many underground, smooth, round, brownish tubers

Leaves: originate from base of each stem; shiny

Flowers: spikelets are yellow-brown and form at the end of many slender branches of unequal length

Habitat: invades cultivated agricultural lands with moist soils

Yellow starthistle
Centaurea solstitialis

Plant: annual; 2-3 ft.; heavily branched, winged stems covered with cottony hair; Sunflower family

Leaves: deeply lobed at base; unlobed and sharply pointed on upper stems

Flowers: yellow; growing singly at ends of branches; sharp thorns up to 3/4 inch long surround flower heads

Habitat: various soil types, usually on roadsides and waste areas

Plant images provided by:

- British Columbia Ministry of Agriculture & Food
- University of California Statewide Integrated Pest Management Project
- Brousseau California Flora Pictures
  Berkeley Digital Library Project
- Information Office of the University of Florida FAS, Center for Aquatic Plants (Gainesville)

Appendix G

Breeding and Selection of Superior Plants for Use in Reclamation

Fourwing saltbush
Atriplex canescens

"Breeding and Selection of Superior Plants for Use in Reclamation"

Summary Report

Breeding and Selection of Superior Plants for Use in Reclamation

October 1998

by Dr. Howard C. Stutz
Professor of Botany, Emeritus
Brigham Young University

for

Navajo Coal Company and San Juan Coal Company
BHP World Minerals

Summary Report of Plant Genetics Studies at the BHP-Minerals Mine in Northwestern New Mexico, 1976-1996

Dr. Howard C. Stutz
Brigham Young University

Summary Report
Breeding and Selection of Superior Plants
For Use in Reclamation

Howard C. Stutz

Executive Summary

In 1976, a study was initiated at the BHP Navajo Mine to develop genetically improved plants for use in reclamation of mine spoils. The methods used were similar to those used in genetic improvement of agricultural crops except that the products were intentionally made genetically heterogeneous.

The principal plant species used in the studies belong to the genus A triplex of the family Chenopodiaceae, which comprises almost all plants that can grow in harsh conditions such as those present on the mine spoils in northwestern New Mexico. Perennial species of A triplex are superior to other Chenopod species for reclamation for several reasons including their C4 photosynthetic pathway, evergreen leaves, dioecious flowering habit, and abundant variation. There are more than twenty known species of perennial A triplex, most of which are genetically enriched because of multiple chromosome races (e.g., seven in A triplex canescens) . Moreover, A triplex is highly palatable and nutritious and is therefore a preferred forage plant for wildlife as well as livestock in many areas.

Two principal methods were used in the studies to generate abundant variation: 1) Selection of high performers from products of interspecific hybrids; and, 2) mixing seed collected from contrasting ecotypes of a species, all of the same chromosome number.

The principal results of this work, including parallel studies not directly related to the development of genetically improved plants, can be summarized as follows:

1. Interspecific hybrids derived from the hybrid *Atriplex canescens x A. obovata* are by far the best performers, based on trials at several sites on all three BHP New Mexico mines.

2. The best seed mixes are of tetraploid ecotype populations of *Atriplex canescens* collected in Colorado, Montana, Nevada, New Mexico, and Utah, and mixes from hexaploid populations of *Atriplex canescens/ A. tridentata, A. obovata,* and interspecific hybrids derived from intercrossing these species. Seed collectors, such as Granite Seed Co.,present collector for BHP, can harvest seed from these populations for use by BHP.

3. Revegetation plots where selections and seed mixes have been sown can be used as seed sources for future revegetation efforts.

4. A study of rooting-depth of mature *Atriplex canescens* plants was conducted to determine how deep fly-ash should be buried at Navajo and San Juan Mines, to avoid having toxic levels of selenium in *A. canescens* plants growing over it. As more than 90% of the roots

of mature *A. canescens* plants occur in the top 2.5 meters of soil, it was determined that *A. canescens* could be safely grown over fly-ash containing selenium if it is buried to a depth of three meters at Navajo Mine and two meters at San Juan Mine, rather than six meters as previously required by the regulatory authorities.

5. A study of the annual species *Proatriplex pleiantha*, found at Navajo and San Juan Mines, was conducted to determine if it needed protection as an endangered species. The results of this study, which determined that this plant is relatively abundant, led to removal of *Proatriplex pleiantha* from the Navajo Nation and the State of New Mexico endangered species protection list and down listed from a Category C2 to C3 on the Federal Endangered Species list.

6. A study of damping-off, due to fungal infection, was conducted to determine the cause of seedling failure in *Atriplex* at Navajo Mine. Laboratory investigation established that the failure was due to infection of young seedlings by *Pythiaceous* fungi. When seed was coated with fungicide before planting, plant establishment was dramatically successful, indicating that routine treatment of *Atriplex* seed with fungicide may be warranted.

7. Results of the studies have been presented to BHP in many reports, and more than 40 scientific papers have been published. Four Masters (M.Sc.) theses and two Doctorate (Ph.D.) dissertations were derived from the studies.

Acknowledgments

During the course of the study designed to develop superior plant selections for use in reclamation of mine spoils, numerous collaborators made significant contributions. Sincere appreciation is extended to each of them. Although it is not possible to name each one, the following are among those who contributed most:

1. The leadership and management support of BHP Minerals (formerly Utah International Inc.) without which this study would not have been possible.

2. Generous financial support provided by Arizona Public Service Company (APS) and BHP Minerals.

3. Argonne National Laboratories (ANL), Brigham Young University (BYU),Northern Energy Resources Co. (NERCO), Public Service Company of New Mexico - San Juan Generating Station (PNM) and U.S. Forest Service (USFS), contributed essential support.

4. Among the individuals who provided abundant assistance and encouragement throughout the years are: Former BHP Minerals employees Stratford Murdock, David Crouch, LeRoy Balzer, John S. Anderson, Wayne Sowards, Dennis Hunter, Sterling Grogan, Chase Caldwell, John Blueeyes, Mimi Benally and Ernest Diswood; former mine managers John Atkins, Wes Karna, Bob Diederich, John Grubb, Jim Rothwell, and Paul Schipke; present Navajo Mine mine manager Ed Pettigrew; current BHP Minerals employees Roger Nelson, Walt Ruzzo, Bill Skeet, Orlando Estrada, Pete Denetclaw, Charlene Gorman, Luci Davis,Dave Porterfield, Tim Ramsey, Dennis Wuertz, Fred Samson, Jes Gleason, Leonard C. Begay, Watson Bradley, Corrinda Jackson and Evelyn Barber and the many other BHP Revegetation crews who provided labor and operational shills to complete the job.

5. A special thanks to Ralph Carter and Ray Hinchman at ANL and Becky Green and Chet Skillbred NERCO, who were particularly helpful during the early years of the study as procedures and philosophies were being formulated.

6. Another special thanks to personnel at BYU who were deeply involved in the studies, including Stewart Sanderson, Ge-lin Chu, Boyd Murray, Mildred Stutz, Craig Stutz, Mark Landeen, Paul Foote, and more than one hundred undergraduate students who earned some of their educational costs by working on the proj ect.

7. And another special thanks to long time Navajo Engineering Construction Authority (NECA) workers, like Julius Gilmore, Leonard Willey, Tyler Teswood and Ramie Nelson and the ten's of other NECA workers who labored in the fields to get the work done.

Summary Report
Breeding and Selection of Superior Plants for Reclamation

H. C. Stutz

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* Foot Note: The following abbreviations will be used in the Table of Contents and report headings to indicate which Mine the information is referring to.
(N)– Navajo Mine, (SJ) – San Juan Mine, (LP)– La Plata Mine

I. Objectives

In 1976 a plan was adopted by personnel from Broken Hills Proprietary (BHP), formerly Utah International Inc., Brigham Young University (BYU), and Department of Energy/Argonne National Laboratories (DOE/ANL) for the development of superior plants for use in reclamation of mine spoils at Navajo Coal Company's Navajo Mine in Northwestern New Mexico (see figure 1) . The products (selected plants) of the project were to have the following favorable attributes:

1. High levels of adaptation to the climate and soils at the mine site
2. High seed production 3.
3. High seed germination
4. High seedling establishment
5. High biomass productivity
6. Rich genetic variation
7. Capacity to be machine harvested
8. Capacity to withstand machine harvesting

It was anticipated that about 20 years would be required to develop such products. All of these attributes have been obtained in some of the selections.

During the course of the project, a few additional studies, having somewhat different objectives, were included. The five principal added studies are:

1. Rooting-depth studies of fourwing saltbush (*Atriplex canescens*). This study was undertaken to determine the effective root-zone depth of *A. canescens* in order to establish the appropriate burial depth of selenium-bearing fly-ash over which *A. canescens* could be safely planted.
2. Studies of the distribution and biology of *Proatriplex pleiantha*, a short lived annual growing in some areas on the Navajo Mine lease (see figure 1) and on "badlands" landscapes elsewhere in the Four-Corners area of New Mexico, Colorado, and Utah, to determine if it merits protection as a "threatened" or "endangered" species.
3. Studies of possible damage from SC>2 to native plants near the Arizona Public Service (APS) power plant.
4. Studies of seedling failure in *Atriplex* due to "damping-off", caused by *Pythiaceae* fungi.
5. DNA studies of *Asclepias sanjuanensis* and its near relatives to determine the magnitude of genetic variation between taxa.

The original studies focused on developing superior plants for use in reclamation at the Navajo Mine. In 1987 the study was expanded to include San Juan Coal Company's San Juan Mine. In 1990 some limited studies were initiated at San Juan Coal Company's La Plata Mine.

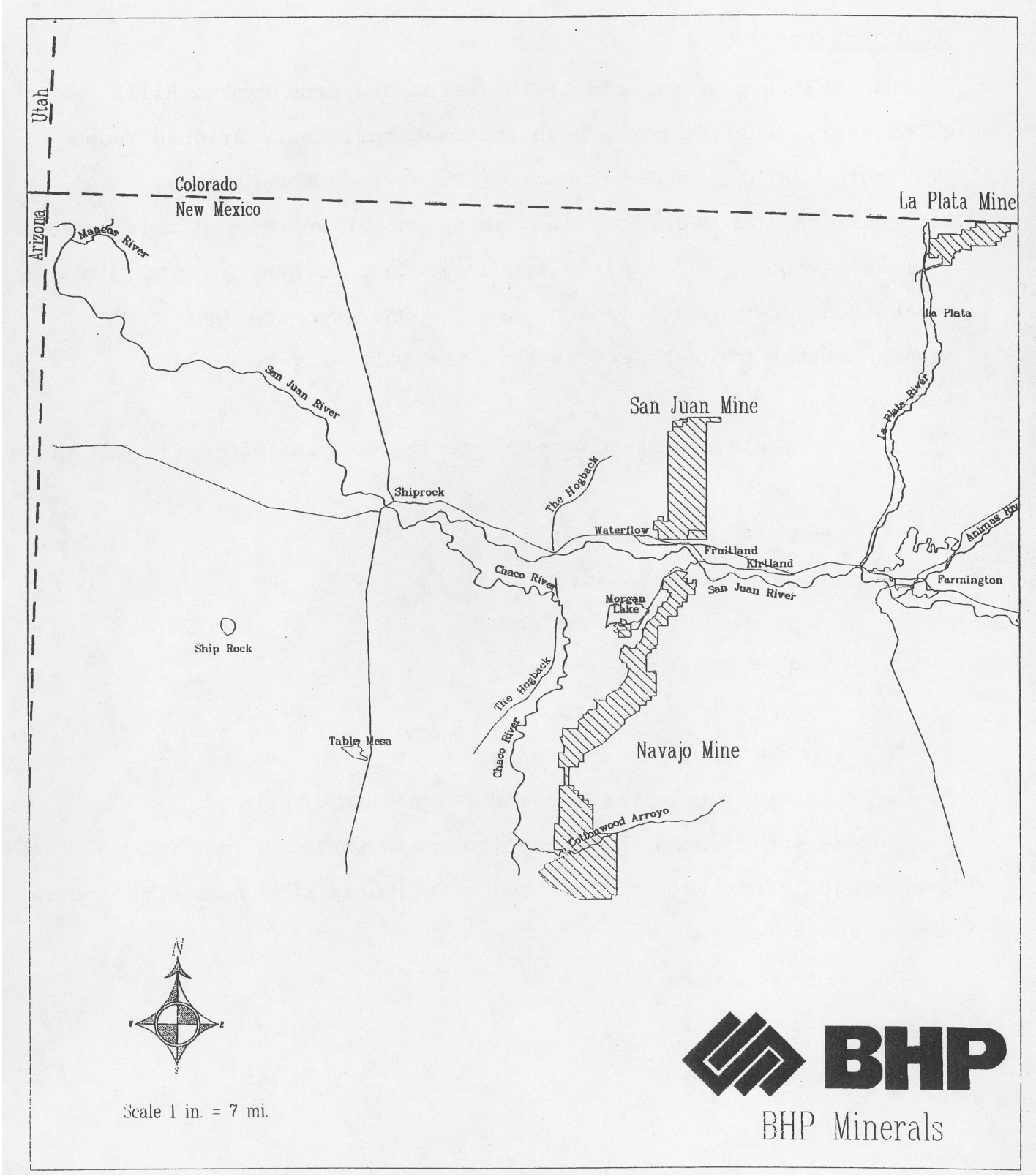


Figure 1. Location of BHP Minerals' Coal Operations- Northwestern New Mexico

II. Background

1. The meaning of diversity

Regulations at the Office of Surface Mining (30 CFR 816.111) and the State of New Mexico's Mining and Minerals Department (CSMC 80-1 20-111) require revegetation of mined lands with a vegetative cover that is "diverse, effective, and permanent". The *diverse* component of this regulation is usually interpreted to mean species diversity. Its significance, however, extends far beyond the limits of species a is meaningful at four distinct levels:

a. Within individual organisms

b. Within species

c. Within communities

d. Within associations

a. *Diversity within individual organisms* is referred to as *plasticity*. Highly plastic plants can adjust to environmental fluctuations and are therefore most common in unpredictable environments. Long-term exposure to stable environments results in selection for plants having low plasticity. Because disturbed site such as mined lands are highly unstable, plants having abundant plasticity (figure 2.) are more likely to be successful on such areas than those which have been selected for narrow, restricted ecological niches. The most likely sources for

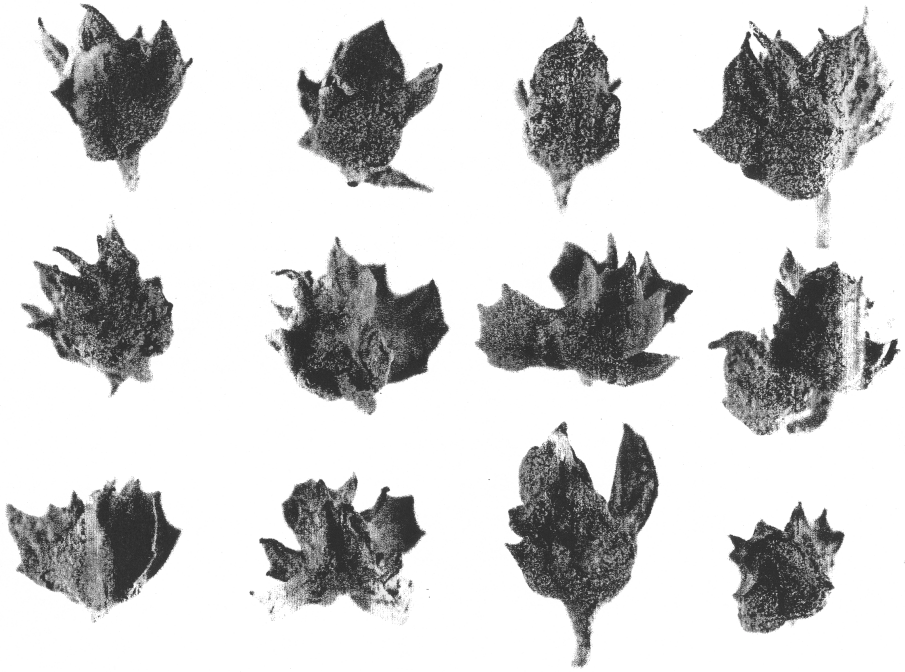


Figure 2. Plasticity in fruits in one plant of *Atriples "nevadensis"*

successful introductions on disturbed sites are, therefore, collections derived from rapidly changing, unstable habitats, or from new genotypes such as those derived from mutations or hybridization that have not yet experienced long-term selection.

b. *Within-species diversity* results from genetic difference between plants and is referred to as *genetic flexibility*. As with plasticity, genetic flexibility is always reduced by natural selection in stable, predictable habitats. It is therefore highest in plants that live in rapidly changing sites and in plants that have acquired genetic diversity by hybridization. Without abundant genetic flexibility, organisms are unable to occupy the numerous microenvironments that characterize newly disturbed sites nor c they survive the array of ecological changes that follow disturbance.

Since hybridization provides the greatest amount of genetic flexibility, in the shortest possible time, hybrid products are, far the best candidates for use in reclamation efforts. *Narrow-basedgenotypes such as those derived from single-source collections from varietal release, or from certified seed developed by intense selection, are the* ***worst*** *possible choice.*

Within-species genetic flexibility can also be obtained by pooling several collections of the same species derived from differing ecological sites (figure 3) . This is particularly useful with polyploid races of the same species wherein a particular chromosome number may have been derived repeatedly, da nova.

c. *Diversity within communities* is a function of species richness. New habitats are often initially saturated by monocultures of species that get there "firstest with the mostest". This is true of many of the valleys of western North America that became suddenly available 10-12,000 years ago when the Pleistocene lakes which had filled them, dried up. Vast acreages are now occupied by monocultuures of species such as winterf at (*Ceratoides lanata*) , greasewood (*Sarcobatus vermiculatus*) , saltsage (*Atriplex tridentata*) , gray me (*Kochia americana*) , or shadscale (*Atriplex confertifolia*) (figure 4).

In time, successional changes be expected to modify and enrich these populations, as evidenced by the presence elsewhere of these same species as components of species-rich communities (figure5).

Acquiring species-rich communities in nature requires a very long time: centuries or millennia. However, by deliberately introducing selected

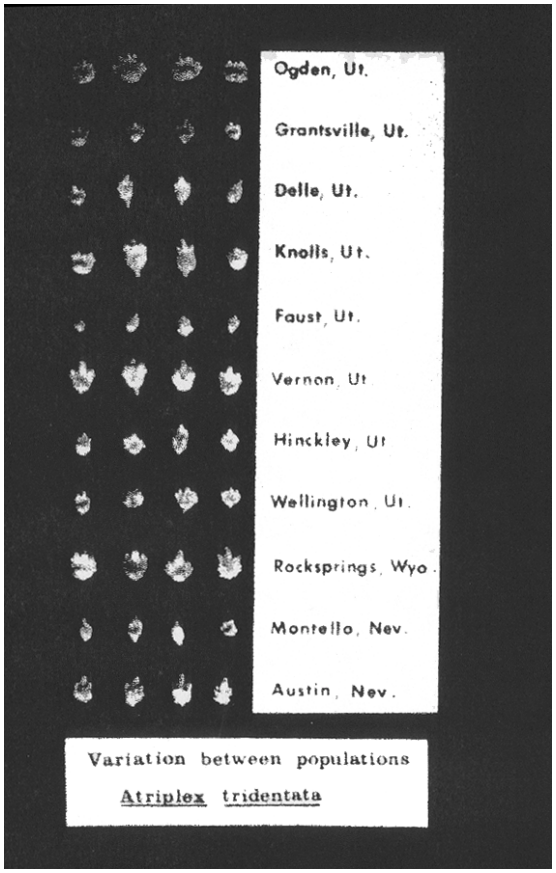


Figure 3. Variation between populations of hexaploid (6x)
At. tridenta

Atriplex confertifolia

Figure 4. Genetically uniform population of tretraploid (4x) *At. confertifolia*

mixtures, species-rich communities can be provided on disturbed lands almost ”instantly”. Not just any concoction will be successful however, and knowledge of the biology of each component species is essential. Southern species will not likely succeed at northern latitudes nor will sand-loving species likely succeed on heavy clay soils. It is also unlikely that anything but wind-pollinated species will be able to reproduce because the appropriate insect or bird pollinators for introduced species will almost certainly be initially absent. But beyond such conspicuous judgements, mixtures of species, each of which has sufficient within-species heterogeneity to permit a good deal of failure, provide the most promising prospects.

Atriplex confertifolia

Figure 5. Genetically diverse population of *At. confertifolia* (2x) in a rich community containing many species.

d. *Diversity within associations* stems form diversity at all other levels. Rich association consist of may kinds of organisms, including plants,

microorganisms and animals, all tied together in functional food webs and reproductive opportunities.

In some instances, attaining adequate association-diversity will require erecting rock piles, developing ponds, treating soil with inocula, or introducing livestock. It must always include extensive plant diveristy in order to provide a variety of root systems, several canopy heights and densities, several seasons of flowering and seed production, both evergreen and deciduous habits, a range and variety of palatabilities for herbivores, etc. In such associations, component species can perpetually contribute and continually evolve to become evermore productive. Such associations in nature are the most attractive, the most dynamically stable, the most productive, and they can be achieved on disturbed lands if the gates to diversity are opened wide at all levels. However, because each species must have within-species diversity to survive, a few genetically flexible species is far better than numerous non- flexible species each of which is subject to extinction because of a rigid, homozygous genotype.

2. Breeding superior plants

The procedures for breeding superior plants for use on disturbed lands is exactly the same as those used by nature. They are also the same procedures that have been used by horticulturists and agronomists for breeding superior plants for agricultural purposes, with one major difference: in agriculture, because the horticultural and husbandry conditions can be carefully controlled, high success can be achieved with pure-bred products. This is not the case in nature nor can it be the case with plant materials prepared for use on disturbed mine lands. Because natural conditions continually change, variable germplasm is absolutely necessary. Whereas with cultivated plants, careful control of such factors as insects and weeds and fertilizer and date of harvest and herbivore pests is not only possible but expected. None of these stabilizing treatments will attend either the evolutionary process in nature nor the establishment of plants on disturbed lands. Neither will they allow for plant succession to proceed. *Certified seed*, or other such homogenous germ plasm will therefore *rarely be adequate for use in rehabilitation of disturbed mine lands* because in the process of development, the genetic base becomes deliberately reduced and will therefore be insufficient to accommodate the array of environmental variables that is always found on every disturbed site, nor the array of new challenges that will unavoidably come as the ecosystem itself evolves.

3. Why Atriplex?

Although many plant species have been involved in the breeding and selection studies at the mines, shrubby species belonging to the goosefoot family (Chenopodiaceae) have predominated. This is so because these are almost the only plants that can accommodate salt-desert conditions and hence the challenges that are similar to those found on mine spoils. Many other plant species can grow in dry desert climates and many can grow in saline soils, but almost without exception, only those plants that belong to the goosefoot family can exist where there is both high salinity

and low precipitation. The principle shrubs in this family are species of *Atriplex* (saltbush) (figure 6), *Ceratoides* (winterfat), *Sarcobatus* (greasewood), *Grayia* (hopsage) , *Kochia* (gray molly), and *Suaeda* (seepweed).

Atriplex Canescens

At. ca gigantea (2x)

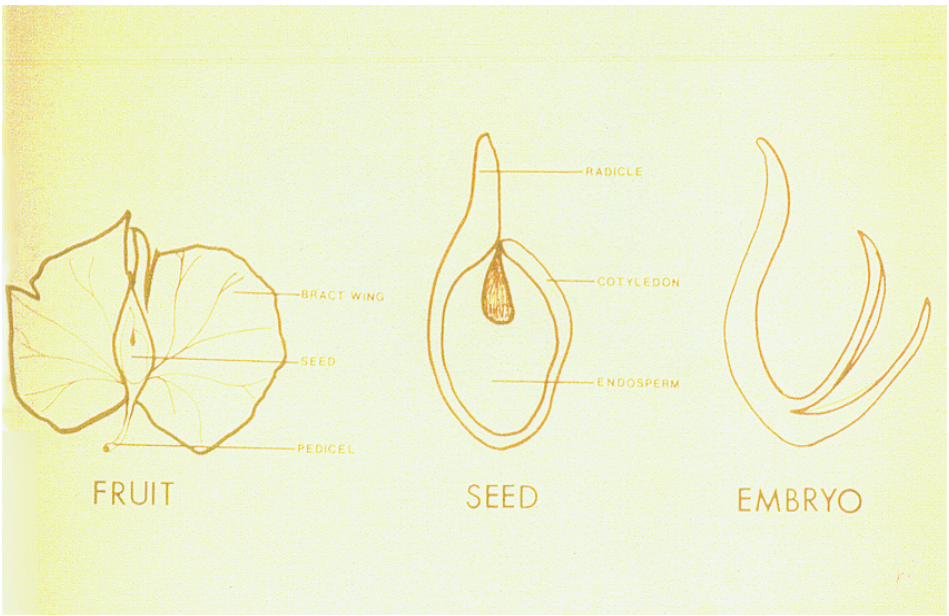


Figure 6. Fruit, Seed and Embryo of At. canescens

Among these, *Atriplex* is, by far, the best candidate for providing superior selections for use in reclamation. Whereas each of the other genera have only one or two species, A triplex contains more than 20 species (figure 7). Selection for improvement in *Atrip!ex* is therefore comparatively easy. *Atriplex* species also have separate sexes (male plants and female plants) which thereby makes interspecific hybridization easy. Furthermore, *Atriplex* shrubs are uniquely evergreen and are therefore available for forage year around. They also utilize 04 photosynthesis, which provides them a distinct advantage in hot, dry climates. Fortunately, also, most A triplex species are highly palatable and nutritious to wildlife and livestock and provide a favorable habitat for numerous species of birds, insects, mammals and reptiles.

Perennial Chenopod Genera

Numbers of Species in Perennial Chenopod Genera

Allenrolfia	1
Atriplex	20+
Ceratoides	1
Grayia	2
Kochia	2
Salicornia	3
Sarcobatus	2
Sueda	3
Zuckia	1

Figure 7. Number of Species in perennial Chenopod Genera

III. Methods

1. Experimental plots

Research plots were established at the three mines and at BYU (see maps in Section VII). These include the following:

a. Nursery plots

b. Hybridization plots

c. Selection ("S") plots

d. Testing ("T") plots

e. Seed Increase Selection ("SIS") plots

f. Field Trial ("FT") plots

g. Bulk Selection ("BS") plots

h. Synthetic hybrid ("Syn") plots

i. Seed orchards

j. Revegetation plots using genetically selected seed-mixes

k. Ecotype-selection plots

a. Early in the studies, *a nursery plot* of approximately two acres, was established at BYU (figure 8a), in which numerous accessions of Chenopods (mostly *Atrip!ex*) have been planted for use in hybridization and other studies described below.

b. Seven *hybridization plots* were established along a Utah highway right-of-way, near BYU, in which only female plants were grown. When pollen became available from male plants grown in the BYU nursery or from plants growing in nature, it was dusted on the female plants to produce "synthetic" hybrids.

c. *Selection ("S") plots* were established at the mines in which plants were grown showing any potential for succeeding on the mined soils. They were introduced as seedling transplants and as seeds. At the Navajo Mine numerous plant specimens were planted in the Bighan 9 "S" plots (figure 8b) . The rows, numbered from west to east and spaced three feet apart, run north to south. Each row is divided into four sections (A,B,C,D), each containing thirty plants. The first plot to the north (S1000), and subsequent alternate plots (S1200, S1400) received transplants; the rows in the second plot (SHOO) immediately south of S1000, and in subsequent alternate plots (S1300) were sown with seeds from numerous plant species. Later, transplants were placed in portions of SHOO and S1300 where no seedlings appeared from the sown seeds.

At the San Juan Mine, numerous *Atriplex* accessions were transplanted in the fenced "S" plot at Pinon. The rows, numbered from south to north, run west to east. They are three feet apart (six feet in some), 300 feet long and contain plants placed three feet apart (six feet in some).

The first 90 feet was sown in 1986 with seeds from *Atriplex "nevadensis"* but since this showed poor performance it was disced in 1989 and planted with transplants. The second 90 feet received transplants; the next 90 feet received seeds of *Zuckia arizonica*, *Purshia tridentata* and *Rhus trilobata* none of which showed good performance. The next 90 feet was sown with seeds of *Atriplex "cunescens"*. They have shown fair to good performance. The next 90 feet was sown with seeds of *Atriplex "obescens"* (*At ca* x *At ob*) (figure 9) selections. They have performed superbly. The remainder of the plot received transplants.

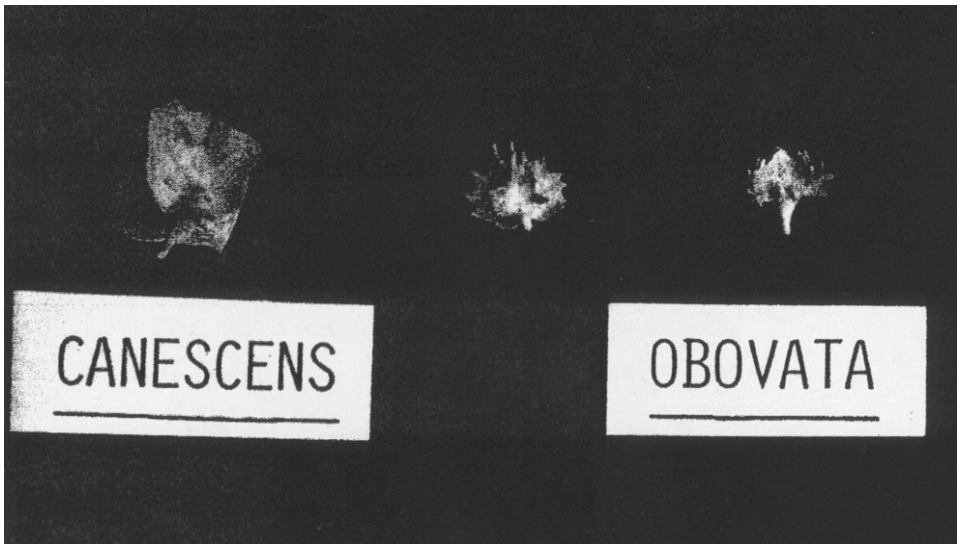
Outside and to the north of the fenced "S" plot, more *Atriplex "obescens"* (*At ca* x *At ob*) seed was sown in a area of about two acres. These have also shown excellent performance.

An "S" plot was established at La Plata Mine commencing in 1993. The rows, six feet apart, 200 feet long, run north to south. They are numbered west to east and each contains 32 plants spaced six feet apart. The best performer here is also the *At ca* x *At oh* selection.

Figure 8a. BYU Nursery

Figure 8B. Navajo Mine Selection “S” Plot

Atriplex canescens x *At. obovata*



F1 Hybrid

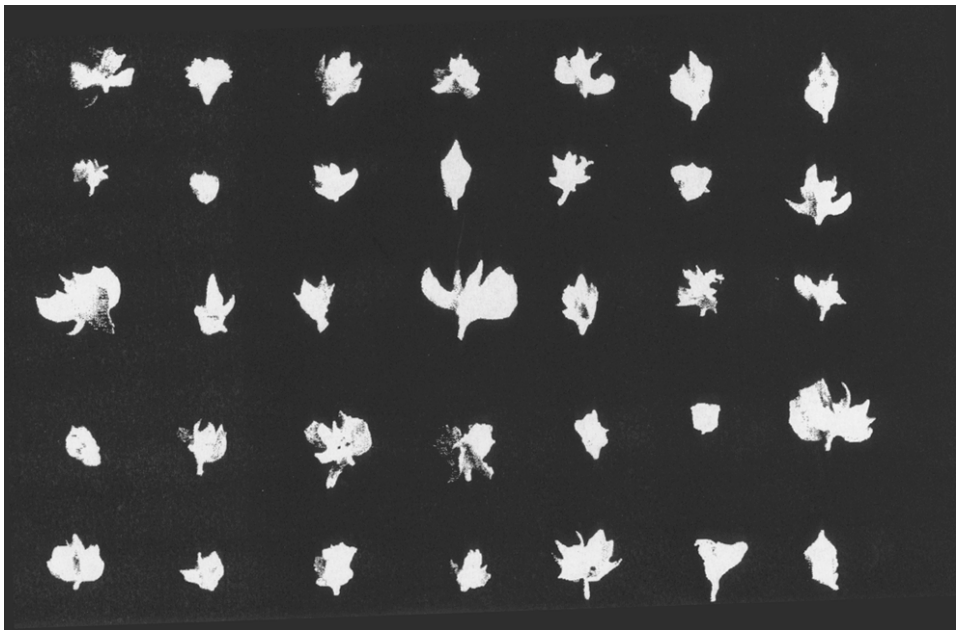


Figure 9. Segregants from *At ca* x *At ob* Hybrids (Each Fruit cam from a different plant)

d. *Testing ("T") plots* were established at the Navajo Mine in which were grown those plants that performed best in the "S" plots. In the "T" plots, performance of each accession was tested with and without supplemental water and fertilizer.

e. *Seed-Increase-Selection (“STS”) plots*, each about one-acre in size, were established at the Navajo Mine. Each plot contains about 1200 transplanted seedlings derived from those accessions that performed best in the "S" and "T" plots. In each case, they were obtained from genetically rich parents so as to deliberately maintain a broad gene pool. Seeds from the best performers in an "SIS" plot were used to produce seedlings for a second "SIS" block. Seeds from the best of those in the second "SIS" block were used to establish a third, and seeds from this block were used to establish a fourth block, etc. It was planned to have five rounds of such seed-increase-selection for each successful group.

In 1992, seeds were harvested from "volunteer" seedlings in the Navajo "SIS II-A" plot (at Bighan highwall) and used to produce plants for initiating a "volunteer-selection" plot across the road west from "SIS II-A" in which selection can continue to provide products (selected plants) that have demonstrated high adaptation to the climate and soils of this area.

f. *Field Trial ("FT") plots*. Extra seeds derived from SIS plots were planted on mined soils at the Navajo Mine and San Juan Mine as a part of the regular revegetation seed mixes. Of the ten "FT" plots that were initiated, seven were from *At ca* x *At ob* selections, three were from *At ca* x *At tri*.

g. *Bulk Selection (“BS”) plots*, in these, trials were made of some of the more promising species and hybrids by sowing directly into small plots (1-3 acres) within revegetation sites at the Navajo Mine. In these, the regular seed mixes contained the experimental seed instead of the prescribed *Atriplex* seed.

The following Bulk Selection plots were established at the Navajo Mine:

1. At Doby 15, several *Atriplex* species were planted in small plots on 19 April 1983. These included *Atriplex laciniata* (dubbed "Java"), *At cu* x *At co* ("Jes"), At ca x At cu ("Corrinda"), *At ca* x *At rob* ("Evelyn"), *Atriplex polycarpa* ("Rose"), *Atriplex spinifera* ("George"), *Atriplex dinosaurensis* ("Bill"), *Atriplex navajoensis* ("Leonard"), *Atriplex bonnevillensis* ("Rick") and *At corr* x *At co* ("Julius").

2. At Bighan 9-10, five contiguous Bulk Selection plots, each approximately two acres in size were sown on 17 July 1984 with Atrip!ex confertifolia selections. Section 1 was sown with a 2X selection from Rush Valley, Tooele Co., UT; Section 2 with a 4X selection from Navajo Mine; Section 3 with an 8X selection from Deseret, Millard Co., UT; Section 4 with a 10X selection from Snake Valley, Millard Co., UT; and Section 5 with a 6X collection from Cortez CO.

3. At North Barber, eight contiguous plots, each about three acres in size were sown on 31 October 1984 with seeds from several Atriplex species at the rate of about 3 lbs/acre.

4. At Doby 10-12, four contiguous Bulk Selection "BS" plots were sown on 12 April 1985. Section 1 (approximately five acres, the southernmost section) was sown with seed from A triplex "obescens" (At ob x At ca) (figure 10) selections and At £Q seed collected from South Lowe; Section 2 (approximately seven acres) was sown with (approximately 20 acres) was sown with x *Atriplex tridentata* (figure 11) and *At co* collected from Lowe; Section 3 seed from *At ca* x *At tri (Atriplex canescens*), *Atriplex cuneata* seed collected from North Barber and *At co* seed collected near Area III headquarters; Section 4 was sown with *At co* seed collected near Area III headquarters and *At ca* collected from plants growing at Doby 10.

5. At North Barber, two contiguous topsoiled "BS" plots, each about three acres in size were sown on 27 August 1990. One was sown with seed from 4X *Atriplex aptera* and 2X *Atriplex confertifolia*; the other was sown with seed from 6X *Atriplex confertifoiia* and selections from the hybrid 6X *Atriplex caneseens* x 6X *Atriplex tridentata*.

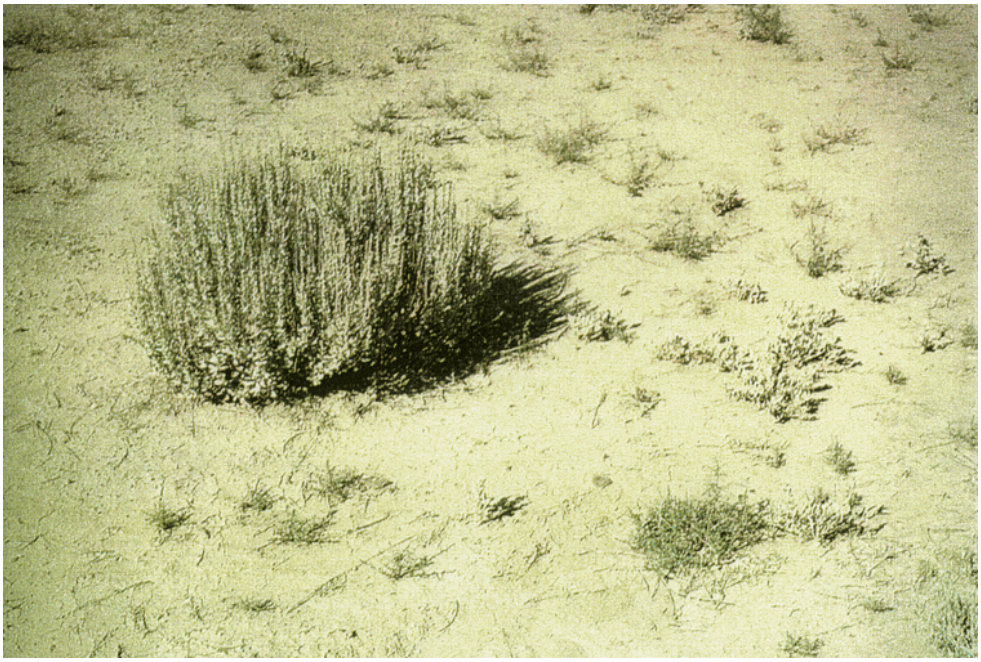
6. At South Hosteen, four contiguous Bulk Selection plots each about one acre in size, were sown on. 29 August 1990. Plot A was sown with approximately seven lbs. of *Zuckia* x *Grayia* seed; Plot B was sown with approximately 14 lbs. of *Atriplex tooelensis* (*At ca* x *At tri*) seed; Plot C was sown with approximately 20 lbs of *Atriplex dollyvardenensis* seed and Plot D was sown with approximately 20 lbs.of *Atriplex lahontanensis* (*A. nuttallii*) seed. Each plot also received approximately five lbs of Russian wild rye.

7. At Yazzie 3, four contiguous Bulk Selection plots were sown 10 October 1990. Plot A was sown with seed from *Zuckia* x *Grayia* hybrids; Plot B was sown with seed of *Atriplex tooeiensis*; Plot C was sown with *Atriplex dollyvardenensis* seed and Plot D was sown with *Atriplex lahontanensis* (*A. nuttallii*) seed.

8. At Bighan Ramp 8, four contiguous Bulk Selection plots were sown on 19 October 1990. Plot A was sown with seed from *Zuckia* x *Grayia* hybrids; Plot B was sown with seed from 6X *Atriplex "tooeiensis"*; Plot C was sown with seed from *Atriplex dollyvardenensis*; and Plot D was sown with seed from *Atriplex lahontanensis* (*A. nuttallii*).

9. Four contiguous Bulk Selection plots were sown at the Hosteen spoil fire on 20 October 1990. Plot A was sown with *Zuckia* x *Grayia* seed; Plot B, with *Atriplex tooeiensis* seed; Plot C with *Atriplex dollyvardenensis* seed; and Plot D with seed from *Atriplex lahontanensis* (*A. nuttallii*).

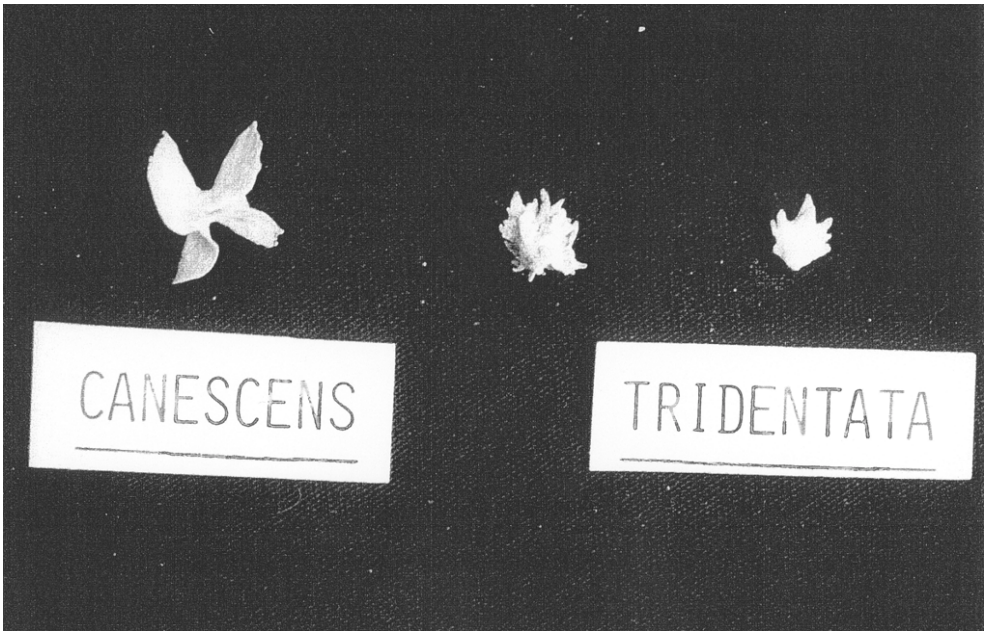
Atriplex obavata x *At canescens*



"Volunteer" seedlings from *At ob* x *At ao* – Dodge Ramp 10 -12

Figure 10. *At ob* x *At ao* – Population

Atriplex tridenta x *A canescess*



At ca Fi Hybrid *At tri*

Figure 11. *At ca* Fi Hybrid *At tri*

h. *A Synthetic; Hybrid ("Syn") plot* was initiated 1 December 1982, on the west side of the haul road, south of Dodge Ramp 4 at the Navajo Mine, in which hybrids produced in the hybridization plots at BYU were grown for study.

i. *Seed Orchards* in order to obtain abundant seed of selections that have shown repeated superior performance in experimental plots, seed orchards were established at various sites from which harvests can be made throughout future years. Because selections from the hybrid *Atriplex obovata* x *A. canescens* (figure 10) appear to be superior to all other selections, seed orchards have been established at Doby 12 and Yazzie, Navajo Mine; Gravel Hill and Pinon, San Juan Mine; and South Knight, La Plata Mine.

j. *Revegetation plots* were established at the Navajo and San Juan mines using genetically selected seed mixes. Some of the seed mixes contained seed collected from native populations of tetraploid (4X) *Atriplex* species. These included several ecotypes of *Atriplex canescens*, *Atriplex corruga ta*, (figure 12) *A triplex confertifolia*, *Atriplex cuneata* (figure 13) and *Atriplex gardneri* (figure 14). Other seed mixes contained seed collected from hexaploid (6X) species. These included selections of *Atriplex obovata*, (figure 15) *Atriplex tri den tata* (f igure 16), *Atriplex confertifolia*, *Atriplex canescens*, and *Atriplex canescens* x Atriplex obovata hybrid derivatives .

k. *Ecotype-selection plots*. Immediately north of the Volunteer-Selection plot, at Bighan highwall, Navajo Mine, several accessions of *Atriplex cuneata* and *Atriplex aptera* were transplanted into an "ecotype- select ion" ("ES") plot. Each of these species have sporadically shown high performance in other plots on the mines, suggesting that in this area some ecotypes are superior to others. Consequently this plot can provide a demonstration of those ecotypes which may be profitably used in reclamation seed mixes. The ecotypes that have been examined thus far in this plot are all tetraploids (4X) .

Atriplex corrugata

Figure 12. Cattle grazing *At corrugata* (mat saltbush)
Bookcliffs, UT

Atriplex cuneata

Figure 13. Cattle grazing *at cuneata* (castle-valley clover) Shiprock, NM

Atriplex Gardneri

Figure 14. *Atriplex Gardneri* (4X) Bighorn Basin, WY

At obovata

Figure 15. *At obovata* (6X) South of Shiprock, NM

Atriplex tridetta

At tri (4X) Juab, Co., UT

At tri (6X) Unitah Co., UT
Figure 16

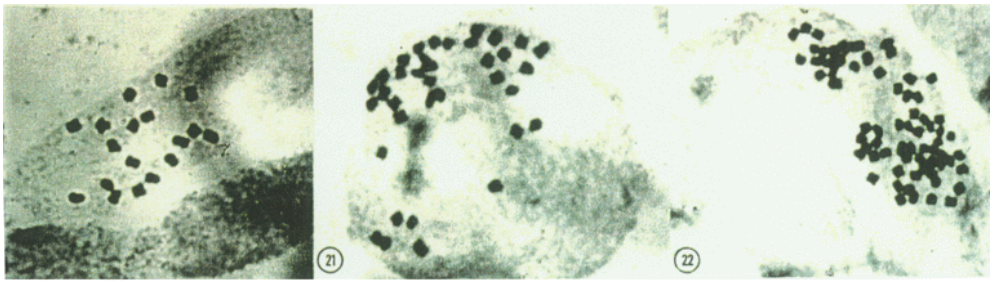
2. Cyrological studies

Cyrological studies were made of the important genera and species of Chenopods and maps prepared to show the geographical distribution of chromosome races (f igure l7). Some of the chromosome counts were obtained from root tips of seedlings; most were obtained from pollen mother cells in immature anthers of male flowers. In each case the tissue to be examined was fixed (killed) in 5% acetic acid (vinegar) , stored in 70% ethyl alcohol, and stained in aceto- carmine. The tissue was squashed in the carmine stain and observed under oil immersion with a compound microscope at about lOOOx magnification.

3. Laboratory studies.

A triplex species can sometimes be distinguished by their chemical differences. Two chemical differences that have proven useful in this respect and which were relatively easy to determine were: (1) differences in flavonoids and (2) differences in saponin content. For each of

Chromosome Races



Diploid	Terraploid	Hexaploid
18 Chromosomes	36 Chromosomes	54 Chromosomes

Figure 17. Hexaploid (54X) Atriplex Canescens, west of Tooele, Tooele County, Utah

these, leaf tissue was ground-up using a mortar and pestle. For saponin assay, a series of dilutions of the leaf tissue in water was added to human red blood cells. Because saponins lyse blood cells, an assay of the saponin content of the leaves of a plant was easily obtained by determining the dilution required to stop hemolysis. No hemolysis results from tissues of plants that produce no saponin.

The flavonoid contents of leaves were determined by two-way paper chromatography.

Some differences between species and varieties were also detected with DNA studies. In these studies, DNA extracted from a small amount of leaf tissue was induced to replicate rapidly

in solutions containing short units of commercially prepared DNA. Those units of DNA in the plant tissue that are similar to those of the commercial DNA units, quickly become abundant. Because similar plants will replicate similar DNA units, differences and similarities between plant groups are thereby easily determined.

4. Field studies

Extensive field studies were required throughout much of Western U.S., Southwestern Canada, and Northern Mexico, particularly in those regions dominated by salt-desert conditions, in order to become acquainted with potential candidates for use in the plant improvement studies and also to learn of the evolutionary processes that could be used in the experiments. As a part of the field studies, seeds were collected for use in the experimental nurseries, flower buds fixed in preservatives for chromosome studies, plant specimens collected for reference and morphological studies, samples of plant tissue obtained for chemical analyses, and notes made of the distribution and ecology of the species that appear to have potential for use in the genetic studies.

Measurements of plant stature (height and width), plant gender (male, female, or both), and leaf size (length and width) was made on twenty plants in several native populations of each of the major species of *Atriplex* under study. In some instances measurements were made of plants growing in nurseries and also of young seedlings.

5. Soil Analysis

Soil samples from populations of several major species of *Atriplex* were analyzed for pH, electrical conductivity, and structure. The samples were taken fro the top 2-6 inches of the soil, after first removing th surface duff. In most cases, the samples were obtained three widely separated locations within populations. Each sample was analyzed separately and the information then combined to provide an average for the three samples.

A comparative analysis was also made of the soils occupied by different chromosome races of some of the *Atriplex* species.

6. Greenhouse studies

Seedlings of the plants that were later transplanted to experimental plots were all started in the greenhouses at BYU. Seeds collected from promising species in nature were planted in 12" x 24" flats in a sterile soil mix. Young seedlings having at least two leaves (other than the cotyledons) were transplanted to 2" x 2" x 5" "root-trainer" containers. The most vigorous of these seedlings were later transplanted to gallon cans or directly to the experimental plots. Some greenhouse-grown plants were used in the laboratory studies, some were used in cytological studies, and some were used in determining morphological characteristics.

7. Root-Depth studies

In order to determine the depth of the effective root zone of A triplex canescens, pits were excavated at Navajo Mine, in late December 1986, with a backhoe, alongside eighteen *A canescens* plants. Two of these plants were growing on undisturbed sites near the mine site, the

other sixteen were mature plants growing on reclaimed mine spoils. A variety of sites (8) were included in the choice of plants that were selected for excavation in order to compare root depth of plants growing in the following circumstances:

a) Reclaimed soil (14) vs. native soil (2)

b) Growing in swales (6) vs. growing on slopes (8)

c) Growing in soils over buried fly-ash (4) vs. non-ash (10)

d) Growing in topsoiled reclaimed soils (4) vs. non-topsoiled (10)

Two of the 18 excavated plants were in areas that did not permit them to be used in these comparisons.

In each of the excavated pits, roots of A canescens were collected by removing 1000 cc samples of soil form a vertical transect in 25 cm consecutive increments. Each sample was poored into a bucket of water containing calcium chloride in order to facilitate separation of the roots from the soil. Using sieves, all roots in each sample were extracted and placed in diameter size-classes ranging from < 0.05 mm to5.0 mm.

- Actual root lengths were measured on roots over 1.0 mm in diameter; the lengths of smaller roots were obtained by estimation, using as indices small samples that were measured in detail.
- Root weights were obtained for three diameter size classes: <1mm, 1-5 mm and more than 5 mm.
- Root volumes were calculated by multiplying root length by r^2 where r was the average radius of each class.
- Root surface-areas were calculated by multiplying root length by average root circumferences (d) where d was the average diameter in a diameter class.

8. *Proatriplex pleiantha* studies

Proatriplex pleiantha, first discover by Weber in 1949 from a population in southwestern Colorado, was found growing on the Navajo Mine 1n 1979. Originally described as a species of *Atriplex*, it became of interest, botanically, because it is completely unlike all species of *Atriplex* in several fundamental attributes. Unlike any *Atriplex*, it produces multiple flowers between two subtending bracts and also unlike *Atriplex* each flower has a rudimentary perianth. Because of these peculiarities, a detailed study was initiated to determine more of its biology and to attempt to interpret its phylogenetic relationships within the family Chenopodiaceae.

During these studies, interest in its biology also grew from a concern that it might be sufficiently limited in numbers and distribution to warrant special management. Consequently, extensive studies were initiated to determine its distribution range, its reproductive potential, its response to ecological variables, factors impacting its germination and establishment, and other aspects of its biology that might contribute to formulating decisions about possible needs for its protection.

9. Seedling-failure studies

Repeated seedling-failure in a plot near Yazzie pit at the Navajo Mine in 1990-1992 promoted a study to determine the underlying causes of the failure. The seed selection that had been used had repeatedly shown high germination and seedling performance at several other sites including plots at the Navajo, San Juan and La Plata Mine's. Consequently, the study examined other possible factors including problems with soil content, time and depth of seeding, methods of seed handling and storage, competitoin with other species and presence of pathogens.

10. DNA Studies of San Juan Milkweed (*Asclepias sanjuanensis*)

Because of some concerns about the welfare of natural populations of San Juan milkweed, a few preliminary studies were initiated to learn more of its biology and it taxanomic status. Some authors recognize for closely related species of dwarf milkweed in western U.S.: *Ascslepsias uncialis*, *A. eastwoodiae*, *A. ruthia*, and A. *sanjuanensis*. Others (eg. Sundell, 1990) lump the all together as varieties or morphological phases of, A. *uncialis*. The taxonomic treatment is of significant concernbecause if they are all of one species, their wide distribution and abundance minimizes the threat of human activities to its survival. If, however, they are separate genetic entities, each may warrant some protection.

As an initial investigation of their genetic affinities, RAPD markers were used to detect genetic differences in plants of *A. sanjuanensis* and *A. ruthiae*

As shown in the attached report, prepared by Kevin Cook and Laurie Jackson, two graduate students at BYU, the primers used in the study showed a few genetic differences between these two taxa but the differences were not abundant, suggesting that the two taxa might be considered to be separate varieties but not separate species.

Further comparative DNA studies of these and other taxa may be useful in clarifying their genetic relationships.

11. Use of genetically selected *Atriplex* seed mixes.

Most species of perennial *Atriplex* occur at several chromosome races. There are seven chromosome races of *A. canescens*, five of *A confertifolia*. This results in two significant management problems in preparing seed-mixes for reclamation that Atriple seed:1) sowing seed from two or more different chromosome races can result in sterile hybrids, and 2) each native population of polyploid *Atriplex* is usually very low in diversity because most polyploid populations arise from a few ancestral parents.

Solutions to both of these problems can be obtained simply be pooling seeds harvested from several ecotypes, all within one chromosome level. This is now being accomplished by having harvests compiled from several populations of known chromosome number. Currently this is being accomplished at the hexaploid (6X) level in both *Atriplex canescens* and *A. confertifolia*. There are many populations of 4X and 6X *A. canescens* throughout western United States; most *A. confertifolia*. populations are tetrploid.

12. A Study of Possible SO_2 Damage to the Vegetation West of the Four Corners Power Plant

At the request of Mr. Donald G. Koch, APS, and examination was made 31 August and 1 September 1979, of *Atriplex confertifolia* plants of the Four Corners Power Plant in Northwestern New Mex to determine if the plants were damaged and, if so, to determine possible causes. Emphasis was given to detection of any possible $S0_2$ damage.

13. Establishment of *Atriplex* seed orchards.

The advisability of having on-lease seed-orchards for obtaining large quantities of seed of superior selections of *Atriplex*, stems from the following considerations:

a. Restrictions on collecting seed from native populations on both public and private lands, becoming more severe,
b. Uncertainty of having favorable weather conditions results in uncertainty of adequate annual seed crops,
c. Local seed orchards will allow long-range assessment of performance of major selections.

Three sites of about 10 acres each, have been planted with selections from the hybrid *Atriplex obovata* x *A. canescens*; 1) South Knight, La Plata Mine, 2) Yazzie Plot, Navajo Mine, and 3) Gravel Hill (88) , San Juan Mine.

The Gravel Hill (88) plot at San Juan Mine was sown in July, 1988 as a component of a standard seed mix in which the prescribed *At ca* content was replaced by an *At ca* x *At ob* selection. It has performed very well and seed was harvested in the fall of 1992, 1993, and 1994 for inclusion in reclamation seed-mixes elsewhere on the mines.

The South Knight plot at the La Plata Mine was sown 19 March, 1992, with no other plant species included. The plants are now vigorous, diverse, and productive. Seed harvested from this plot in 1994 was used to sow contiguous areas, thereby enlarging the plot size to about 15 acres.

The Navajo Mine Yazzie plot was first sown in October, 1990. It was a complete failure; not one seedling emerged. It was resown in March 1992. This also was a complete failure. As described in the attached report, a study designed to discover the cause of the dramatic failure of a selection that had shown superior performance elsewhere, revealed that the failure was due to "damping-off" of the seedlings caused by *Pythiaceous* fungi. Seeding in August 1993, with seed treated with fungicide resulted in a satisfactory establishment.

Future supplies of At ca x At ob seed appears to be ensured by yields from these established "Orchards" as well as from other smaller stands at the Pinon plot, San Juan Mine and the Doby 12 plot, Navajo Mine. As other revegetation plots that included At ca x At ob selections in the seed-mixes, they too can provide a valuable source of *At ca* x *At ob* seed.

Seed orchards of selections of several tetraploid *A. canescens* ecotypes have also been started at all three mines. Transplants of several selections were planted in 1993 and 1994 in the Pinon plot at Sun Juan Mine and at the Bighan highwall plots at Navajo Mine. A few selected

ecotypes were also planted at the La Plata Mine in 1991 and 1994 by direct seeding. Two of these, planted in the haul-road plots, produced abundant seed in 1994. The seed was hand-harvested and included in some of the 1995 revegetation seed-mixes. Three other accessions were planted by direct seeding at the Stolenberg plots near the La Plata Mine haul-road in December, 1994.

14. Reports and Publications

Periodically, summary reports were provided to the mine personnel. Some of the oral reports were accompanied by written summaries and some by visits to the experimental plots. Also several reports were presented at professional meetings, relating particular discoveries and accomplishments. Several of these have published in the "Proceedings" of the meetings. Several dealing with new discoveries disclosed by the studies, have been published in refereed scientific journals. Four Masters of Science theses and two Ph D dissertations we derived from the studies.

IV. Results (see attached documents)

1 . Contents of Expeyimental Plots

2. Cytology
   - a. Chromosome counts of A triplex canescens
     - 1. Maps of distribution of chromosome races
     - 2 . Listed by location and by variety
   - b. Chromosome counts of *Atriplex confertifolia* listed by location and by chromosome race
   - c. Chromosome counts of other *Atriplex* species

3. Laboratory Studies
   - a . Saponins
   - b . Flavonoids
   - c. DNA

4. Field, studies; measurements of plants and leaves
   - a. *Atriplex canescens*
   - b. *Atriplex cuneata*
   - c. Seedling measurements

5. Soil Analyses

6. front -Dept-.h studies of Atriplex canescens

7. Proatriplex pleiantha studies

8 . Additinnal studies

a. Asclepias studies

b. Seedling Failure

c. Seed Mixes

d. SC_2 damage

9. Significant Reports

10. Significant Publications

V. Assessments and Recommendations

1. Experimental Plots

a. Nursery Plots (BYU)

1. Assessment . These plots have been valuable in many aspects of the study. They have served 1 identify potential performance of accessions under minimal selection pressures, provided plant materials for laboratory studies, permitted identification of heritability of characteristics of each species, provided pollen for hybridization experiments and portrayed attributes of putative natural hybrids.

2. Recommendationstion .

a. Ideally - Because of their many uses in genetic studies of plants to be used in reclamation efforts, they should be maintained and utilized perpetually.

b. Practically - Because nursery maintenance requires extensive care and considerable expense, their use by mine personnel is probably not possible.

b. Hybridization Plots (BYU)

1. Assessments, in addition to providing numerous interspecific hybrids, the hybridization plots provided important information about the biolo of the species being studied in the project including time of flowering and seed producticcrossability of species, climatic and edaphic preferences, expressions of monoecy and dioecy, phenotypic attributes, magnitude of seed yield, seed production in the absence of pollination and duration of time for successful pollination. In several instances chromosome number was determined for species growing in the plots and information was obtained concerning saponin and flavonoid contents.

2. Recomendations

a. Ideally - Because hybridization plots are easily established, merely by isolating female plants that can later be hand pollinated with pollen from selected males, their continuation would be highly beneficial. Valuable hybrids such as those between drought -tolerant A triplex polycarpa and cold-

tolerant A triplex aptera could never occur in nature but can easily be produced in controlled hybridization plots. Ideally then, their continuation and use would be very valuable.

b. Practically - Although highly valuable, their use involves careful monitoring and maintenance that would be difficult to arrange without the services of a geneticist. Consequently, their use should be suspended.

c. Selection (“S”) plots (N&LP)

1. Assessment . The selection plots are among the most valuable components of the study. In these plots numerous plant species and varieties have been grown and studied. Their performance in the "S" plots have provided the principle indicator of potentially successful accessions. Most introductions failed; some failed early, some in later years. Although these failures were often disappointing, they ultimately became the most valuable indicators of the "winners" . The few that accommodated the harsh environment of the "S" plots were those which ultimately became valuable selections for use in the revegetation seed-mixes. Among the best performers in the "S" plots were hexaploid (6X) selections from *A. canescens* x *A. obovata* hybrids, some of the *A. aptera* (4X) selections some *A. canescens* selections and some (4X) *A. canescens* x *A. cuneata* selections.

2. Recommendations

a Ideally - Because "S" plots are easily installed, maintained, and interpreted, their use should be perpetuated forever.

b. Practically - Continue to introducepotentially useful species in the existing "S" plots. Water them weekly during the 1st growing season, then let them go. Those that will be useful in revegetation of the mine spoils will conspicuously survive and reproduce.

d. Testing "T" Plots (N)

1. Assessment:. Early in the plant genetics studies the "T" plots were established to assess the value of providing supplemental water and/or fertilizer to accessions being tested for use in revegetation. It was a labor-intensive experiment and very little conspicuous useful information was obtained. Consequently, they have not been perpetuated.

Probably the most valuable piece of information that was gleaned from the "T" plots was derived from the performance of A triplex canescens x A. polycazpa hybrids. In the design of the "T" plots, accessions were provided four treatments:

-supplemental water plus NPK fertilizer

-supplemental water without fertilizer

-no supplemental water with fertilizer

-no supplemental water with no fertilizer

Several accessions survived with supplemental water, with and without fertilize but only one, *A triplex canescens* x *A. polycarpa* survived the first season without water. (Initially each plant in all treatments received one liter of water at the time of transplanting. The *At ca* x *At po* plants all showed good growth (about 30 cm during the summer) following transplanting; all other accessions died. This appeared to be an immediate "winner", but, alas they all succumbed during the subsequent cold winter.

As a result of this experience, synthetic hybrids have been prepared from other *At ca* x *At po* parents in which the *At ca* parent is from Montana. Hopefully selections can be obtained from this parentage that are both drought-tolerant and cold tolerant.

2. Recommendations. Do not continue the "T" plots. The cost and labor do not justify the scanty rewards.

e. Seed Increase- Selection ("S-T-S"} plots (N)

A. "S-I-S" I (*At ca* x *At rob*) Bighan Ramp 7

1. Assessment. An early discovery of hexaploid. *A triplex* "*robusta*" (name not yet publisher in northwestern Utah showed great promise as potential contributor to the species diversity available for mine reclamation in northwestern New Mexico. However, although it grows in a very dry, salty desert, it succeeds along highway shoulders where moisture is locally quite abundant. Consequently *A. "robusta"* is probably not highly salt-tolerant nor drought-tolerant and has not been a good performer in "S" plot trials. However, because *A. "robusta"* x *A. canescens* plants did perform well in "S" plot trials an "S-I-S" plot was initiated to test their performance. At that time it was not known that the parents had different levels of polyploidy; *A. canescens* in that area is tetraploid (4X), *A. tridentata* is hexaploid (6X).

   Many of the plants in "S-I-S" I look good and are well adapted but they are mostly sterile pentaploids (5X) and therefore are of little value in the breeding studies.

2. Recomendations..

   Abandon this plot.

B. "S-I-S" II (*At ca* x *At ob*) Bighan 9 Highwall

1. Assessment. The "S-I-S" II plots containing selections from At ca x At ob parents, have become the "Showplace" for the plant genetics studies. After the parents and their hybrid derivatives had repeatedly shown good performance in the "S" plots, one-acre "S-I-S" plot ("S-I-S" II) was established for them in the corner next Navajo Agricultural Products Industry (I property at the Bighan-9 highwall. In th plot, approximately 1200 plants derived hexaploid (6X) At ca x At ob segregants transplanted (1979) six feet apart, in r six feet apart. Most of the initial transplants are still alive and healthy, addition, several are surrounded by

volunteer seedlings, many of which are n producing their own seed crop. Two years later (1981), a second adjacent 1-acre "S-I-S" plot *At ca* x *At ob* ("S-I-S" II-B) was established with plan derived from seeds harvested from plants the 1979 plot. Seeds from this plot were then used to establish a third, "S-I-S" plot ("S-I-S" II-C) and seed from this were used to establish a fourth plot ("S-I-S" II-D Plants have succeeded in all of these plots but appear to be healthier in the portions of the lots that have heavy clay soils than in those with sandy soils.

In 1992 a one-acre plot was established across the road west of the "S-I-S" 11-A, *At ca* x *At ob* plot, with plants derived from volunteers in that plot. These probably represent the best of all selections because natural selection has been operative 1) in selecting original transplants that produced viable seed, 2) in selecting from these, seeds that had good germination, 3) in selecting seedlings that demonstrated good seedling establishment, and 4) in selecting plants that showed vigorous growth and viable seed production.

2. Recommendations. Because these plots demonstrate the feasibility and wisdom of including genetic studies in preparing superior selections for use in revegetation of mine-spoils, they should remain intact"forever". In favorable years seed harvests can be obtained from them for inclusion in hexaploid (6X) seed mixes. Also new information can be obtained from continuous monitoring.

C. "S-I-S" III (*At ca* x *At poly*) North Daisy Plot

1. Assessment. *A triplex canescens* x *A. polycarpa* hybrids showed high promise early in the genetics studies. Several very favorable products have been derived in nature and some early selections showed performance at the Navajo Mine, particul in unusually high drought-tolerance. However they appear to be severely intolerant of cold temperatures and have now nearly al died out.

2. Recommendation. Abandon this plot unless someone can proceed with selection experiments with hybrids that have been between *A. polycarpa* and *A. aptera* from Montana. Predictably, selected segregants having both drought-tolerance and cold-tolerance could be obtained from this parentage.

D. "S-I-S" IV (At co x At cu) Middle Daisy Plot

1. Assessment. Several species and genotype have been introduced into this plot that showed promise in the "S" plots. Most of them have failed. A few tetraploid. *Sarcobatus vermiculatus* plants are still alive but are struggling. Most *S. vemuculatus* plants are octoploid but these tetraploid selections from Canada were thought to offer some valuable alternatives but they apparently do not. Among the other introductions, only *Atriplex confertifolia* x *A. cuneata* show promise. This is a fairly common hybrid in nature and with long time selection would probably yield some good derivatives. Both parents are highly successful in salt-desert

environments so a selected combination would likely be a very good addition to the already available useful taxa.

2. Recommendations. Enrichment of the *A triplex cuneata* x *A. confertifolia* would be interesting and eventually profitable but since it would require several years of assessment and selection this plot should be abandoned.

E. "S-I-S" V (*At ca* x *At cu*) South Daisy Plot

1. Assessment. This plot contains segregants from the hybrid tetraploid (4X) *A triplex canescens* x tetraploid (4X) *A. cuneata*. This is a common hybrid in nature and in a few places appears to have produced viable adaptive products. Consequently there has been continuing high hopes for obtaining quality selections from them. Although the rewards have been slow in coming, they still appear to be attainable. The first one-acre lot of this selection was established in 1980 and harvested in 1983 and the seed used to produce plants for establishing a contiguous one-acre "S-I-S" V plot in 1984. Since then most efforts have concentrated on replacement of plants which have died out. Some of the surviving plants look good but many are still experiencing a short life leaving no progeny.

2. Recommendations. Although the prospects of obtaining some superior selections from hybrid parentage remain high, it will apparently require several years and considerable labor. Consequently attention to this plot should be terminated.

F. "S-I-S" VI (*At ca* x *At tri*), Bighan Ramp 8

1. Assessment. Several hybrids derived from tetraploid (4X) *A. canescens* x hexaploid (6X) parents were planted assess their potential for use in revegetation seed mixes. This is a common hybrid in nature and several stabilized products have been found from them. Howe-the process of stabilizing adaptive segregants from a highly sterile pentapl< (5X) hybrid is extremely slow and probably completely unfeasible in developing supei selections for use on mine spoils.

2. Recommendations. This plot can be abandoned.

G. "S-I-S" VII -Atriplex tooelensis, (Bighan Ramp 9)

1. Assessment. The "S-I-S" VII plot contains *At ca.* plants collected near Tooele, Tooele County Utah. They are hexaploid (6X) and may have originated from *A. canescens* x *A.tridentata* parents. In this vicinity both of these parents are present and hybrids and hybrid derivatives are common. A supporting observation for this interpretation is provided by the lack of saponins in the *A. tooelensis* plants and in the A. tridentata plants but present in *A. canescens*. In the hybrid populations some plants produce saponins, other do not.

   An alternative explanation for the origin of *A. tooelensis* is that it came from seed that was planted there in the late 1930's from collections made in New Mexico.

Several populations of hexaploid *A. canescens* are known in New Mexico that do not produce saponins and may have been the source of the seed that was sown in Utah in a reclamation effort to revegetate some of the drought-stressed areas.

The S-I-S VII plot has taught us several important lessons. In 1986, alternate rows in part of the plot were clipped to within a few inches of the ground to assess their potential for recovery from severe grazing. Many plants died from the clipping, others survived. A few appeared to be stimulated by clipping and put on abundant new growth.

During the 19 years since this plot was planted, there has emerged a thinning process in which the death of some plants has allowed survivors to flourish. This appears to be a slow process but is apparently a common occurrence in nature wherein most native species attain a rather consistent spacing distance between plants of the same species.

2. Recommendations. Since "S-I-S" VII can furnish new insights concerning establishment, die back, thinning, etc.., it is recommended that it be left intact.

f. Field trial "FT" plots (N&SJ)

1. Assessment. All field trial plots of selections from the hybrid *A. canescens* x *A. obovata* have been conspicuously superb. They have shown good seed germination, good seedling establishment, vigorous vegetative growth, high seed yield extensive between-plant diversity and considerable volunteer reseeding.

   Selections from the hybrid *A triplex tridentata* x *A. canesnens* have shown better performance in some places than others. They appear to be well adapted in all attributes except drought tolerance. In years with elevated levels of precipitation they performed very well; in dry years they showed considerable vegetative die-off and plant loss.

. 2 Recommendations. Use seed derived from *A.obovata* x *A. canescens* selections in all hexaploid (6X) seed mixes. *A. canescens* x *A. tridentata* and *A. tooelensis* are also hexaploid so can be used indiscriminately in these same 6X seed mixes to enrich the genotype pool although their performance will, expectedly, often be lower than that of At ca x At ob selections.

g. Bulk Selections ("BS") plots (N)

1. Assessments. Although almost all "BS " trials failed, a few entities performed sufficiently well to warrant their continued use. Among the best of these are *A triplex canescens, A. cuneata* and *A. obovata*. All other species of *A triplex* that were tried are apparently insufficiently cold tolerant or insufficiently drought tolerant for the climate in northwestern New Mexico.

   Sporadic good performance was noted also for *Zukia arizonica* x *Grayia brandegei* hybrids *Atriplex aptera, Atriplex gardneri* and *Secale montamun*.

2. Recommendations. All 4X seed mixes should include seed from several populations of *A. caneacens, A confertifolia, A.aptera, A. cuneata,* and *A. gardneri*. Diploid (2X) *Zuckia arizonica* could also be included in most mixes because it is likely to hybridize with A triplex. It is one of the most drought tolerant of all Chenopods so should be included in as many trials as possible.

   Secale montanum might also be profitably included in all seed mixes, particularly at San Juan and La Plata mines where higher precipitation would help it. *Secale montanum* is attractive because of its capacity to become dormant both in winter months and summer montl with active growth being resumed in spring and fall. This perennial grass has reproduced significantly in some of the "BS" trials at Navajo Mine but has ultimately disappeared, apparently from its response to drought and a because it is highly palatable to all herbivores.

h. Synthetic hybrids plot (N)

1. Assessments. Nearly all synthetic hybrids fai in the plot established for them. Part of the failure was apparently the result of heavy competition by native species growing in this plot. The "good" soil in the plot permitted very good growth of numerous aggressive native plants. Also, as in nature, hybrids are usually less likely to succeed than are some of the combinations that occur among their progeny.
2. Recommendations. Abandon this plot; it has served its purpose.

i. Seed orchards (N, SJ, & LP)

1. Assessments. The seed-orchards that were, established to provide adequate seed of *A. obovata* x *A. canescens* hybrid derivatives have all succeeded admirably except one near Yazzie pit at the Navajo Nine which repeatedly failed until it was sown with seed treated with fungicide.
2. Recommendations . It is recommended, that seed-orchards be developed, for important species, at least at one of each mine, for the following tetraploids:

   a. *Atriplex aptera*
   b. *Atriplex gardneri*
   c. *Atriplex cuneata*
   d. *Atriplex canescens*
   e. *Atri1ex confertifolia*

   and for the following hexaploids:

   a. *Atriplex obovata*
   b. *Atriplex obovata* x *canescens*
   c. *Atriplex canescens*

   In each case multiple sources are essential.

Because of our experience with seedling failure in a seed-orchard of *A. obovata* x *A. canescens* selections, it is recommended that further studies : conducted to see how widespread this problem might '. and to identify appropriate methods to circumvent t) hazard. In the meantime, since the fungus can be easily and inexpensively controlled by coating the seed with a fungicide prior to seeding, it is recommended that such routine seed treatment of A triplex seeds be used widely in revegetation seed mixes.

j. Preparation of seed mixes from diverse populations of native species, all having the same chromosome number.

Early in the studies, several native populations were found of polyploid *Atriplex* species in which every plant appeared to be genotypically unique but all with the same polyploid chromosome number. This was surprising because polyploid taxa are usually notably genetically very uniform because they ordinarily originate from a single ancestral plant (or at most only a few). Consequently the display of abundant variation within some native polyploid populations was unexpected.

In searching for the source of the rampant diversity in these polyploids, it was discovered that they were hybrid swarms, derived from hybridization between two different polyploid taxa of the same chromosome number.

Bach of the parental taxa were genetically uniform, and as expected of plants having the same chromosome number, fertility in the hybrids and hybrid segregants was not impaired. As a result hybrid products could segregate freely as they do in hybrid derivatives from diploid parents.

Because of the demonstrated explosive increase in diversity that can result from hybridizing genetically contrasting polyploid parents, deliberate encouragement of this process is now being promoted at the mines by preparing seed mixes in which several selections, all of the same chromosome number, are sown together in revegetation plots.

Because most of the large populations of *Atriplex* in western U.S. occur at the tetraploid (4X) or hexaploid (6X) level, emphasis is currently directed to preparing tetraploid and hexaploid mixes.

The tetraploid (4X) seed-mixes contain seed from several ecotypes of tetraploid *Atriplex canescens, A. confertifolia, A. cuneata, A. corrugata,* and *A. gardeneri*. The hexaploid (6X) seed-mixes contain seed from several ecotypes of hexaploid *A. canescens, A. confertifolia, A. obovata,* and *A. "obescens"* (selections from A. obovata x A. canescens hybrid derivatives) .

Other mixes can be prepared at other chromoso levels (*A. canescens* occurs at seven chromosome nu levels: 2X, 4X, 6X, 8X, 10X, 12X, 20X) and *A. confertifolia* is known to occur at 5 chromosome levels: 2X, 4X, 6X, 8X,10X) but should probably be postponed until more experience has been attained the tetraploid and hexaploid mixes.

k. Ecotype- select ion plots (N)

1. Assessments. Although the "ES" plots were only recently established (1994), differences betw ecotypes are conspicuous.
2. Recommendations. Because ecotype differences of very high value in determining the best genotype for inclusion in reclamation seed-mi these should be maintained and, if possible, greatly extended.

2. Assessment and Recommendations of *Atriplex* species

a. *Atriplex canescens* (Pursh) Nutt. (fourwing saltbush)

A. Positive features:

1. Wide distributional range: Canada to cen Mexico and Nebraska and Kansas to the Pacific Ocean.
2. Contains abundant genetic variation.
3. Occurs in seven different chromosome races (2X, 4X, 6X. 8X, 10X, 12X, 20X) .
4. Each chromosome race contains several varieties.
5. Highly nutritious and palatable to livestock and wildlife (Figure 18).
6. Provides good habitat for birds, insects, mammals, and reptiles.
7. Abundant in Four-Corners area; therefore already adapted to the local climate and soils.

Atriplex canescens

Figure 18. Cattle grazing on *At canescens*, Navajo Mine reclaimed mine land.

8. Shows high germination and seedling establishment .
9. Deep root system (2-3 meters) ensures survival beyond a series of adverse years.
10. Individual plants may produce abundant seed.
11. Large extant populations can provide large quantities of seed.
12. Seed harvesting is relatively easy (figure19) .

Atriplex canescens X *At obovata*

Figure 19. Harvesting *At ca* x *At ob* seed with standard crop combine, Navajo Mine

B. Negative

1. Because they often differ in chromosome number, there is a high risk of promoting the formation of sterile hybrids by random mixing of seed from differing populations.
2. Because most populations are polyploid, collection of seed from one large population will usually provide highly homozygous seed (all the same genotype) . When such seed is used for revegetation, its low level of genetic diversity will usually result in failure, either immediately or in the future .

C. Recommendations

1. Always use seed of known chromosome number.

2. Always prepare mixes that contain seed collections that have the same chromosome number .
3. To ensure genetic diversity, always prepare mixes from seeds collected from a variety of ecotypes .
4. Keep 4X mixes separate from 6X mixes.
5. Enrich 4X At ca mixes with seeds from other 4X species (eg. *cuneata, corrugata. aptera, gardneri*) , and enrich 6X *At ca* mixes with seeds from other 6X *Atriplex* species (eg. *obovata*, 6X *tridentata*. 6X *confertifolia*. 6X *At ca* x *At ob*) .
6. Later, develop 2X seed mixes (and 8X, 10X, etc., when possible) .

b. *Atriplex confertifolia* (Torr. & Frem.) Watson (shadscale)

A. Positive features:

1. High tolerance of cold and drought. Many are also alkali- and salt-tolerant.
2. New growth is highly palatable and nutritious.
3. Wide distribution throughout western United States.
4. Contains abundant genetic variation
   a. From polyploidy (5 chromosome races 2X, 4X, 6X, 8X, 10X. Separate origi: of chromosome races ensure abundant between-population variation, even among those having the same chromosome number) .
   b. From hybridization: In nature, the hybrids *At co* x *ca*, *At co* x *cun*, and *At co* x *corr* are common.
   c. From mutations within isolated populations. Many phenotype differer are conspicuous.

B. Negative features:

1. Very low seed germination.
2. Very low seedling establishment.
3. Thorny branches.
4 . Large populations may all have the same genotype. Harvests from these could therefore yield large quantities of homozygous seed that would result in ultimate failure.

C. Recommendations

1. Collect abundantly from a wide spectrum of ecotypes. Mix 4X seed in 4X seed mixes, 6 seed in 6X seed mixes, etc.
2. Locate more populations of known chromosome number .
3. Because of its low seed germination and seedling establishment, overseed *At co* in mixes .

c. *Atriplex corrugata* Watson (mat-saltbush)

A. Positive features:

1. High drought -tolerance.
2. High salt -tolerance.
3. High cold- tolerance.
4. Readily hybridizes in nature with At co and At cu.

B. Negative features

1. Small stature provides very little forage or cover .
2. Low seed-germination (lowest of all perennial Atriplex species) .
3. Difficult to harvest seed (thorny and low statured).

C. Recommendations:

1. Collect widely from tetraploid (4X) populations and include in all mixes containing 4X *cuneata*.
2. Collect widely from diploid (2X) populations and include in all mixes containing 2X *cuneata.*
3. Success is most likely on heavy clay soils.

d. *Atriplex cuneata* Nelson (Castle-Valley clover)

A. Positive features:

1. Contains abundant genetic variation.
2. Hybridizes readily with At ca, At co, and corr.
3. Long-lived.
4. Drought - tolerant .
5. Salt -tolerant.
6. Palatable and nutritious for livestock and wildlife.
7. High seed-germination.

B. Negative features:

1. No volunteers have yet been found in the study plots.

C. Recommendations:

1. Collect widely and use abundantly in seed mixes for revegetation.
2. Keep diploids (2X) and tetraploids (4X) separate .

e. *Atriplex falcata* Standley (beaked saltbush)

A. Positive features:

1. Contains abundant genetic variation.
2. High-seed germination.

3. Hybridizes freely with other species.
4 . Cold-tolerant .
5. Produces early spring forage.
6. Highly palatable and nutritious.
7. Withstands severe grazing.

B. Negative features:
1. Small stature, minimal biomass.
2. Requires good soil.
3. Low drought and salt -tolerance.
4. Small seeds and few seeds from each plant makes harvesting difficult.
5. Most populations occur at the diploid level (2X) and therefore cannot be used in 4X and 6X mixes.

C. Recommendations:
1. Use known tetraploids and hexaploids in corresponding 4X and 6X mixes.
2. Do not use diploids until diploid mixes are developed .

f . *Atriplex gardneri*

A. Positive features:
1. Contains abundant genetic variation.
2. Cold-tolerant.
3. Salt -tolerant.
4. Good soil stabilizer (stem-layering in clay soils) .
5. Germination is fairly high.

B. Negative features:
1. Difficult to distinguish diploids from tetraploids .
2. Genetics obscure.

C. Recommendations ;
1. Intensify efforts to obtain seed.
2. Include in all reclamation efforts at all BHP New Mexico mines.

g. *Atriplex obovata* Moquin (broadscale)

A. Positive features:
1. Native in the Four-Corners area and is therefore already climatically and edaphically adapted.
2. Low palatability; therefore not easily destroyed by heavy grazing.
3. Salt- and alkali-tolerant.

4. All are hexaploid (6X) and can therefore be collected anywhere for inclusion in 6X seed-mixes .
5. Hybridizes easily with other *Atriplex* species.

B. Negative features:

1. Only mildly drought -tolerant.
2. Not cold- tolerant.
3. Useful only in 6X seed-mixes.

C. Recommendations

1. Continue to include in all 6X seed mixes
2. Collect widely to obtain abundant genet i variation.
3. Use interspecific hybrids abundantly, particularly *At "obescens"* (*At ca* x *At ob*) hybrid products.

h. *Atriplex polycarpa* (Torrey) Watson (all scale)

A. Positive features:

1. Very drought tolerant.
2. Contains abundant genetic variation.
3. Hybridizes freely with *A. canescens*, yielding several adaptive taxa (eg. *A. laciniata* Parish, *A. granidentatum* Stutz & Sanderson, *A. macilenta* Jepson) .
4. Occurs in at least three chromosome races (2X, 4X, 8X) .
5. Furnishes acceptable (and often the only) habitat for wildlife on thousands of acres in the warm deserts of southwestern United States.
6. Low palatability permits good survival even under heavy grazing.

B. Negative features:

1. Not cold-tolerant.

C. Recommendations:

1. Because it cannot withstand the cold temperatures of the Four-Corners area, do not use in reclamation efforts.
2. Because it hybridizes freely with *At ca*, cold tolerant selections might be obtained from synthetic hybrids involving *At ca* from northern latitudes. Some of these have already been produced and show considerable promise (eg. *A. poiycarpa* x A. *canescens* var *aptera* from Edgar Montana). If these genetic studies are continued by BHP.this would be an important selection to examine.

i. *Atriplex tridentata*

A. Positive features:

1. Reproduces asexually by root-sprouts.

2. Genetically rich.
3. Withstands heavy grazing.
4. Diploids (2X), tetraploids (4X), and hexaploids (6X) are all available and can. therefore be used at all three levels (the: 6X populations are most abundant) .
5. Cold-tolerant.
6. Alkali-tolerant.
7. Highly palatable and nutritious.
8. Good seed germination.
9. Withstands machine harvesting and/or clipping (and therefore heavy grazing) .
10. Numerous 6X populations occur throughout western U.S.

B. Negative features:

1. Not drought-tolerant.

C. Recommendations;

1. Test a wide array of 6X populations, some appear to be more drought tolerant than others.
2. Search for more 2X and 4X populations then use in 2X and 4X seed mixes.

j . Other southern species

Other southern species that cannot endure the cold temperatures of northwestern New Mexico but might yield valuable hybrid products with more northern taxa include:

A triplex spinifera Macbride (spinescale)

Atriplex acanthocarpa (Torrey) Watson (burscale)

Atriplex barclayana (Benth.) Dietr.

Atriplex griffithsii Stanley

Atriplex hymenelytra (Torr.) Watson (Desert holly)

Atriplex lentiformis (Torr.) Watson (lenscale)

3. Assessment and recommendations of specific projects

a. Cytology

Because chromosome number plays such a dominant role in the biology of A trip! ex, it has become a major component of the genetic studies of these plants. Chromosome races are present in each of the species of Atriplex that has been used in reclamation in North America. *Atriplex canescens*, the most widely used species of *Atriple*x, occurs in seven chromosome races (2X, 4X, 6X, 8X, 10X, 12X, and 20X) . Because hybrids between different races form easily but are highly sterile, it is imperative that seed mixes containing *A. canescens* include only collections that have the same chromosome number.

Atriplex confertifolia occurs in five races 4X, 6X, 8X, and 10X) , *A. cuneata* and *A. corrugata* occur in two races (2X and 4X), *A. tridentata* occur in three races (2X, 4X, and 6X), and *A. obovata* occur in two known races (2X and 6X).

It is highly recommended that chromosome numb be determined for all sources of Atriplex used in reclamation so that each mix will never include more than one chromosome race, so as to guard against the formation of sterile hybrids in future generations

b. Seed Mixes

Not only should seed mixes contain only collections derived from populations having the same. chromosome number, but they should be enriched as much as possible by including numerous ecotypes at each selected chromosome level, of each component species.

It is recommended, therefore, that seed mixes contain as much diversity as possible, both within and between species, but guarding against sterile hybrids by mixing only collections of the same chromosome number.

Currently, seed mixes of Atriplex are being prepared by Granite Seed Co., Lehi, Utah, at two chromosome levels: tetraploids (4X) and hexaploids (6X). The tetraploid mix is made up of the follow: ingredients; *A. canescens* from Pueblo CO, Moab UT, Sunnyside UT, Panaca NV, Wales UT, Willard NM, Uintah Basin UT, Kirtland NM, Jackson Lake NM; *A. cuneata* from Navajo Mine NM, Cortez NM, and Emery UT; *A. confertifolia* from Sevier Co. UT, Uintah Co. UT, San Juan Mine NM, and Antelope Valley UT; *A. corrugata* from Emery UT and Navajo Mine NM; and *A. gardneri* from Sweetwater Co. WY. The hexaploid (6X) mix consists of collections of 6X *A. canescans* from Tooele, Tooele Co., UT, and Bernardo, Soccoro Co., NM; 6X *A. obovata* from Mancos Trading Post, CO, and San Juan Co., NM; 6X *A. tridentata* from Sevier Co., UT; and selections from the hybrids 6X *A. canescens* x 6X *A. obovata* and 6X *A. tridentata* x 6X *A. canescens.*

It is recommended that these 4X and 6X mixes be continued and enriched as much as possible with additional 4X and 6X seed sources.

c. "Damping-off "

Somewhat fortuitously, it was discovered that fungal infections can completely destroy stands of young *Atriplex* seedlings. It was also discovered that dusting the seeds with a fungicide before sowing provides a highly successful remedy. Because fungicide treatment is so easily and inexpensively accomplished, it is recommended that in other reclamation efforts, experiments be continued to assess the wisdom of routinely including fungicide treatment in all new seedings. Treating a portion of the seed being sown and leaving a portion untreated to be sown in a contiguous plot could provide a simple assessment of the efficacy of routine treatment.

Other observations obtained from the studies suggest several other low-cost experiments that could have profound implications:

1) A small area at the Yazzie plot that was covered with clear plastic for three weeks demonstrated that solar heat can also provide effective control of the fungus. Seedling establishment appeared to be at least as successful in the area receiving solar heat treatment as in the area sown with seed dusted with chemical fungicides. It is recommended, therefore, that there be further testing of this treatment.
2) Soils from the "infected" Yazzie plot contained 1,230 propagules of *Pythium* per gram of soil whereas soil from a stockpile at Daisy contained only 20 propagules per gram of soil. Further studies are, therefore, suggested to determine whether or not stockpiling can be an effective control measure.
3) Repeated examination of the Yazzie plot is recommended to determine if there are long-ra benefits or detriments from the fungicide treatment.
4) Seedling failure at the Yazzie plot occurred in selections from *Atriplex obovata* x *A . canescens* hybrids. Are other *Atriplex* species also susceptible?

d. Ecotype-selection studies.

Seed mixes will always profit from increased diversity when accompanied by avoidance of sterility derived from mixing contrasting chromosome races. However, some sources of diversity will expectedly perform better than others on the mine spoils in New Mexico. Consequently, there is wisdom in continuing to study performance of a variety of ecotypes of the principal species of *Atriplex* that are currently being used (*A. canescens, A. cuneata, A. corrugata, A. gardneri , A. obovata, A. tridentata*, and *A. confertifolia*).

Since this will require using nursery stock, it may be prohibitive at the mines unless a plant materials center or native plant nursery can provide designated young plants for outplanting. If this can be arranged, it is recommended that approximately 20 plants representing each available, unique ecotype of each species be planted in a nursery plot, watered liberally for the first season, then left alone for future performance assessment .

VI. Important Discoveries

1. Genetics of Four-wing Saltbush (*Atriplex canescens*)

a. Four-wing saltbush consists of seven chromosome races (2X, 4X, 6X, 8X, 10X, 12X, 20X).

b. Each race contains abundant genetic variation between populations but each population is genetically uniform.

c. Never mix seed collected from different chromosome races—their offspring will be sterile.

d. "Always" mix seed from several populations of the same chromosome number—this will ensure abundant genetic diversity.

2. Roots of Four-wing Saltbush

   a. 95% of the roots of four-wing plants occurs in the top two meters of soil. Therefore, they will not take up toxic levels of selenium from fly-ash buried deeper than two meters. (This information has already been economically valuable for BHP by reducing the burial depth of fly-ash from six meters to three meters.)

3. Seedling Failure due to Fungal Infection

   Loss of all seedlings in some Atriplex trials found to result from infection by soil-borne *Pythiaceous* fungi. A highly successful, inexpensive remedy was attained by coating the seed with a fungicide before sowing.

   Some native soils were found to contain thousands of Pythiaceae propagules; stockpiled soil contained almost none.

4. Volunteer Seedlings

   The best index of successful adaptation of selected genotypes is the production of volunteer seedlings. Of all accessions examined in these studies, volunteers appeared most often around segregants from the hybrid *Atriplex canescens* x *A. obovata.*

5. *Proatriplex pleiantha*

   Our studies showed that *Proatriplex pleiantha* is currently neither rare nor endangered and hence, needs no protection. BHP mining operations do not seriously impact its survival.

6. Biology of Chenopod Annuals

   Studies of *Proatriplex pleiantha* and other annuals in the family Chenopodiaceae revealed the following common biological attributes:

   a. "All" *Atriplex* annuals are either monoecious (both sexes on the same plant) or hermaphroditic (both sexes in the same flower). "All" *Atriplex* perennials are dioecious (each plant is entirely male or entirely female).

   b. Annuals are highly site specific; they occupy very narrow ecological territories.

   c. Most annuals are diploid (polyploid annuals are probably too homozygous to survive a narrow ecology.

   d. Populations of some species of annuals are very abundant in some years and almost completely absent in others. They escape decimation by producing extensive seed-banks in which seeds may survive for many years.

   e. Ecological requirements are so subtle that they of defy detection; very similar-appearing sites, even adjacent sites, may harbor numerous plants, or non

7. Mother Nature Makes Mistakes

Not all that we see in nature is adaptive. In the Great Basin, large populations of species that arrived following the demise of the Pleistocene lakes, 13,000 years ago, have suddenly experienced extensive die back. They were only ephemerally successful. Many arrived solely by chance, not because they were highly adaptive, and were unable to cope with new challenges. Most such failures are homozygous polyploids.

So it is with reclamation. Those which are initially successful may fail with the arrival of new ecological changes. It is important that we mimic Mother Nature's successes, not her failures.

Hybrid swarms are common in the Great Basin. Because of their rich genetic diversity, they do not experience extensive die back. In our genetic studies with *Atriplex*, we have similarly obtained an unusually successful hybrid swarm from the parentage *Atriplex obovata* x *A. canescens*. It is, thus far, highly successful at all three BHP mines.

8. Diversity is needed at all levels: at the level of the individual (plasticity); at the level of the species (genetic flexibility); at the level of the community (species rich) ; and at the level of the ecosystem (many forms of plants and animals). Within-species diversity is the most important of all. It is far better to have few genetically rich species than numerous genetically poor species. Ecological changes can destroy community and ecosystem diversity unless it is based on abundant within-species diversity.

VII. Maps

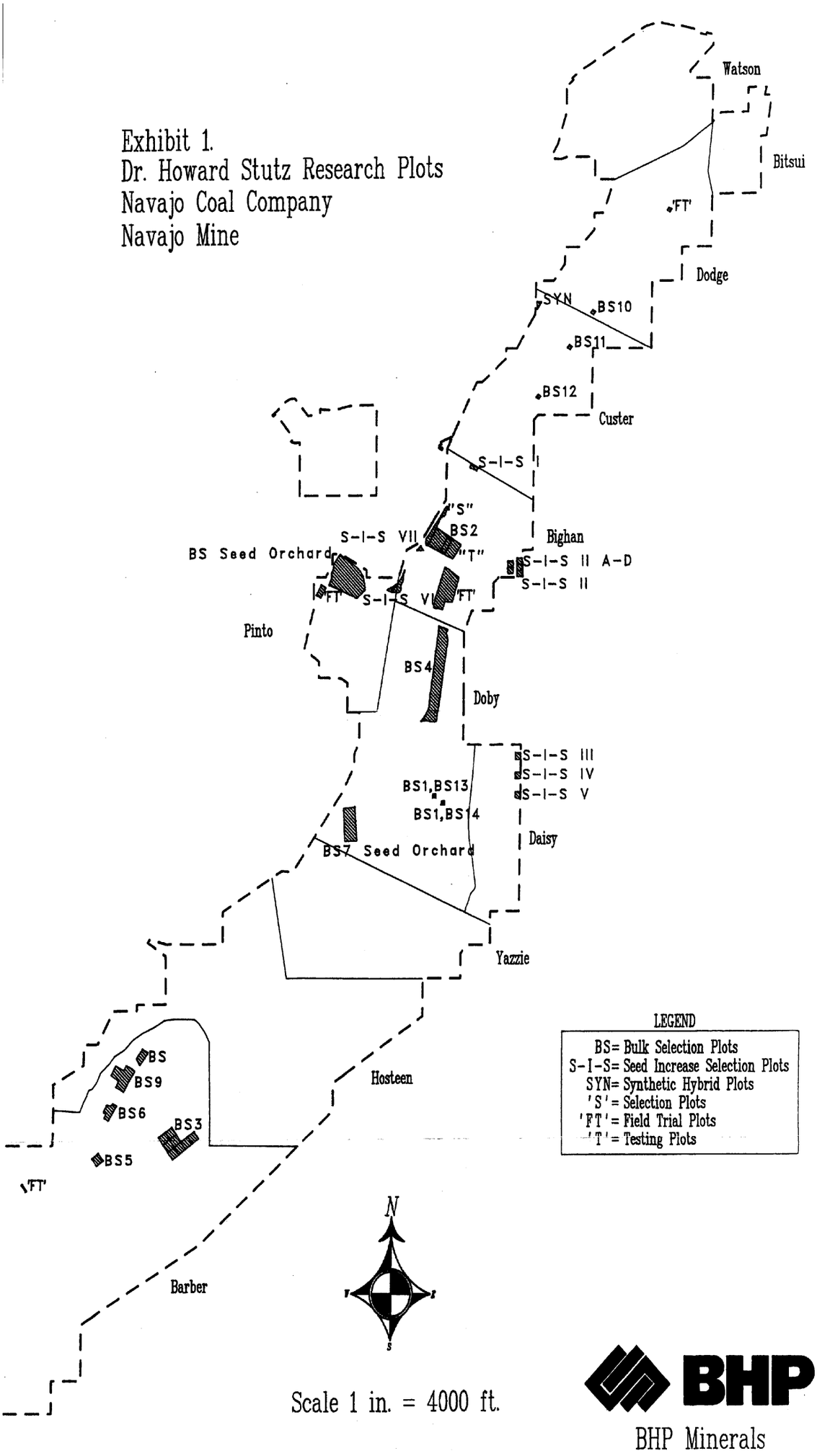


Exhibit 1. Locations of Research plots at Navajo Mine

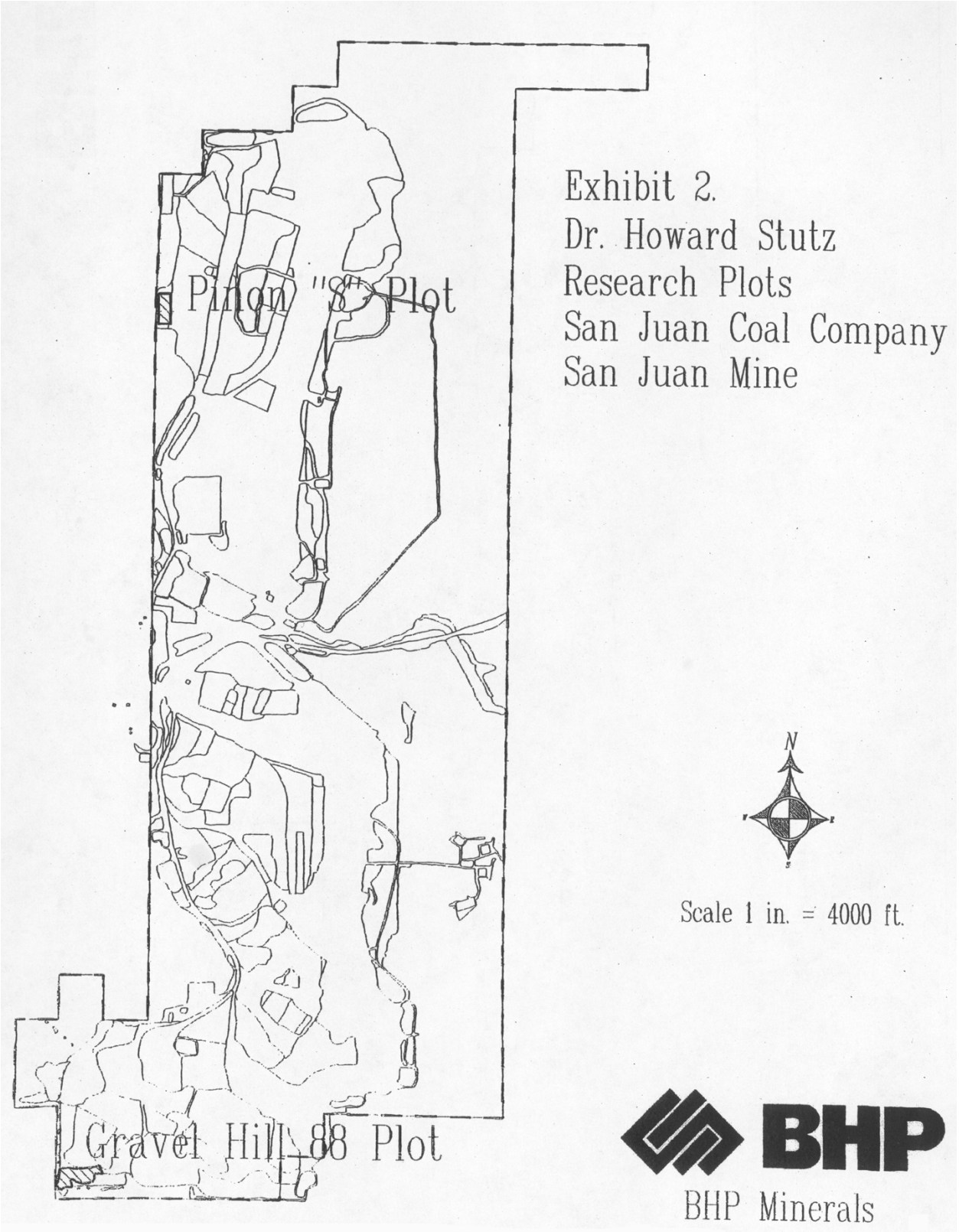


Exhibit 2. Location of Research plots at San Juan Mine.

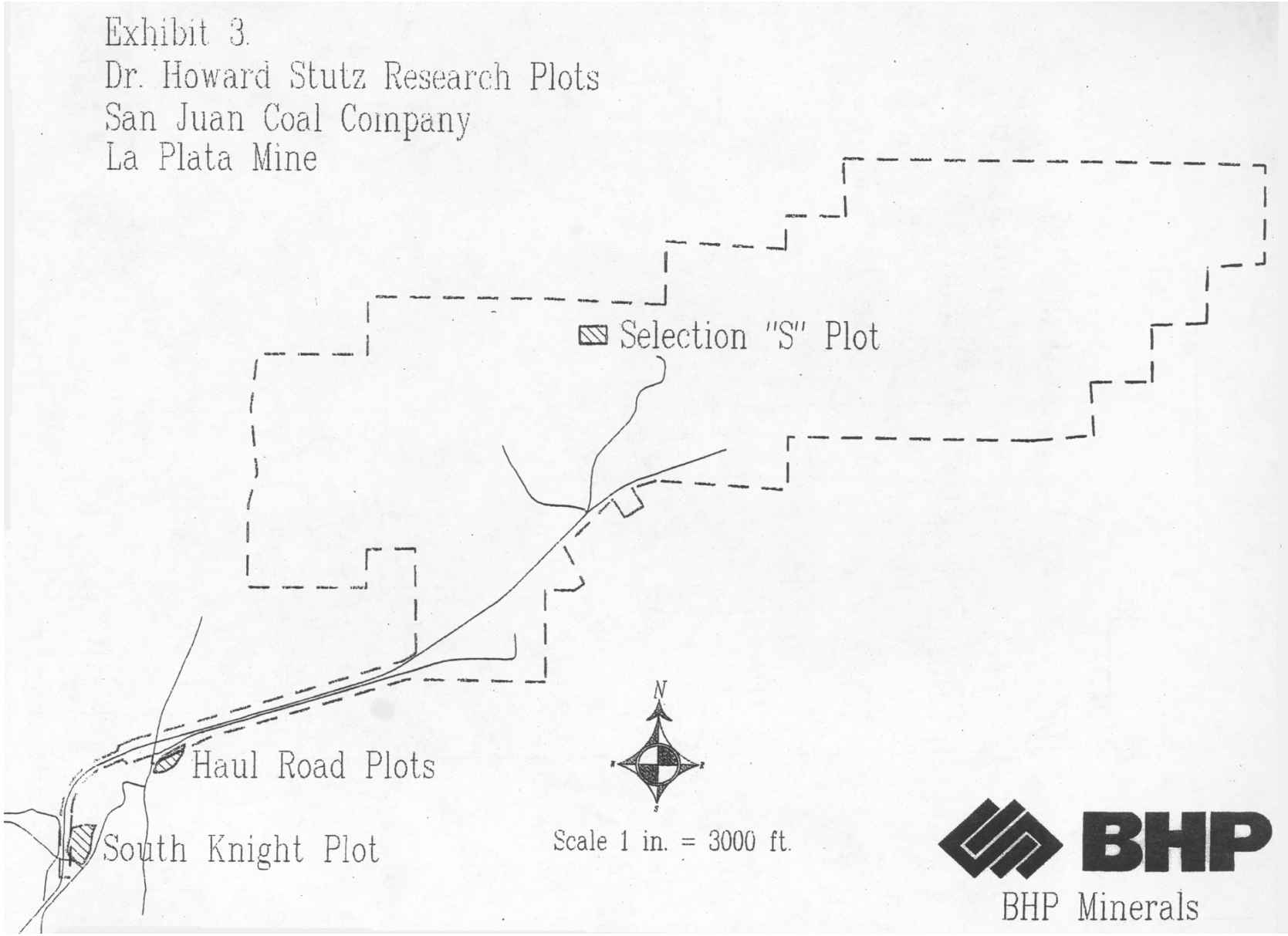


Exhibit 3. Locations of Research plots at La Plata Mine