MIKE PELLANT

United States
Department of
Agriculture

Forest Service

**Technology &
Development
Program**

2200–Range
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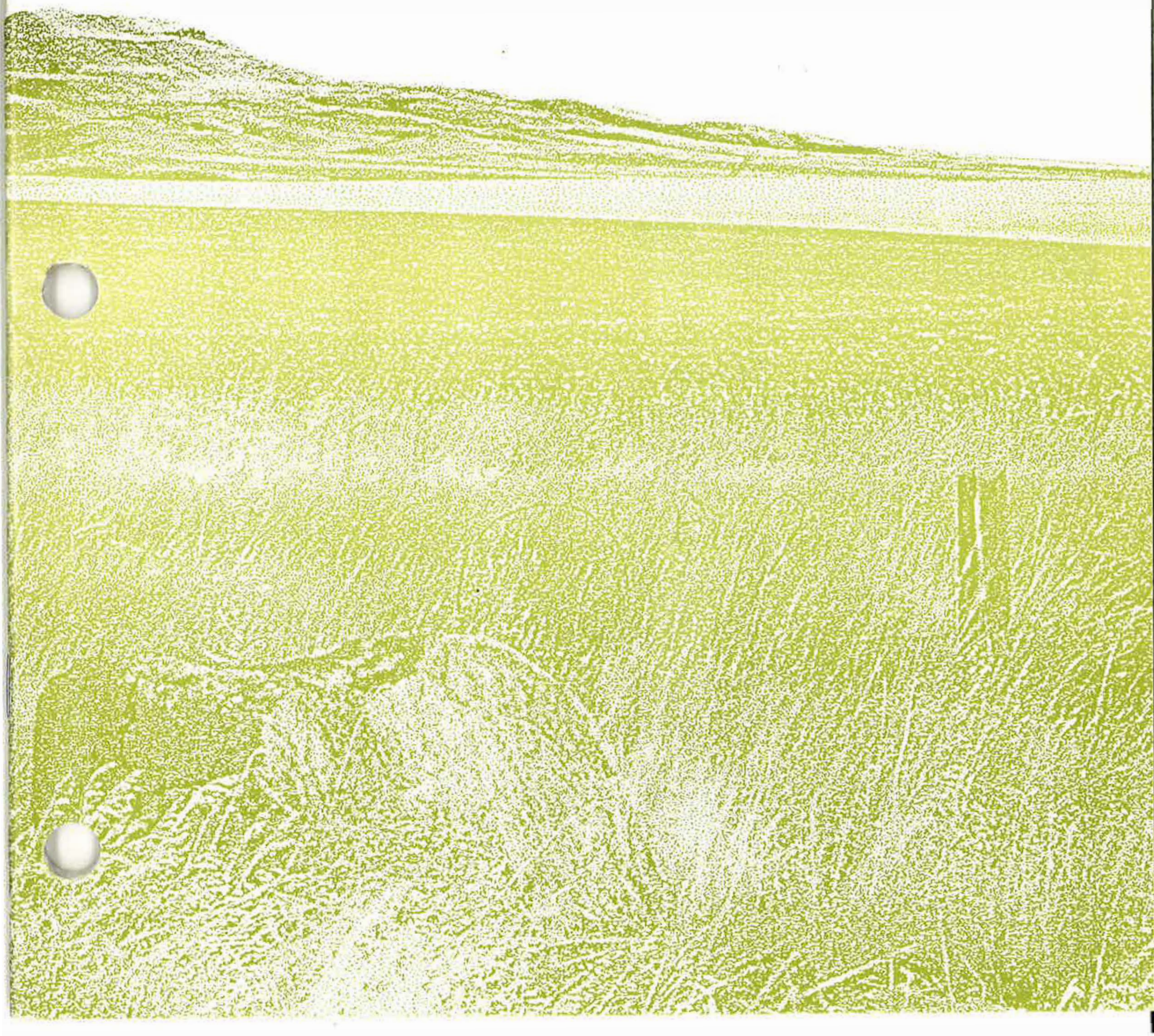
Rangeland Technology Equipment Council

1991 Annual Report



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Sunday, January 13, 1991

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Wildland Resource Management,
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USDA Forest Service,
Intermountain Fire Sciences Lab,
Missoula, Montana.

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USDI-BLM, Boise, Idaho.

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National Plant Materials Specialist -
USDA-SCS, Washington, DC.

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USDI-Park Service, Denver, Colorado.

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Plant Materials Technical Advisor,
USDA- SCS, Denver, Colorado.

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Plant Materials Specialist,
USDA-SCS, Temple, Texas.

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USDA-SCS, Bridger, Montana.

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Texas Agricultural Experiment Station,
Vernon, Texas

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Drawings

Single copies of drawings are available from the Technology and Development Centers without charge.

Write to:

USDA Forest Service
Technology and Development Center
Building 1, Fort Missoula
Missoula, MT 59801

USDA Forest Service
Technology and Development Center
444 East Bonita Avenue
San Dimas, CA 91773

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Reports

Range Handbooks

***Richard G. Hallman*, Program Leader, USDA Forest Service, Missoula Technology and Development Center, Missoula, Montana**

Three range handbooks recently published by the Missoula Technology and Development Center are now available from the Society of Range Management in Denver. These structural improvement handbooks consolidate numerous handbooks now scattered through many federal agencies into three volumes: *Fences; Facilities for Handling, Sheltering, and Trailing Livestock; and Facilities for Watering Livestock and Wildlife.* Each volume describes components uses, advantages and disadvantages, safety and environmental concerns, suggestions for redesign or new concepts for future development. Costs are included where possible. Pertinent books and articles are included in a bibliography in each volume.

Facilities for Handling, Sheltering, and Trailing Livestock, 8724-2809, September 1987. This publication discusses facilities for wildland horse, sheep, and cattle management. The book describes corral systems (pens, alleyways, fences, and gates); restraining devices (loading, working, and squeeze chutes, cradles, and tables); and miscellaneaous facilities such as dipping vats, spray pens, dusting alleys, back rubbers, and scales. Sheltering facilities include sheds, shade shelters, windbrakes, and feeding and watering devices. The section on trailing livestock describes driveways and driftways, low-water crossings, culverts, corduroy log crossings, and bridges. Facilities discussed may apply to wildlife as well as domestic animals, but specific information on wildlife management is not included.

Fences (8824-2803, July 1988). This handbook consolidates information on planning, building, and maintaining fences. Information is included on: gathering site information; locating the fence; choosing a fence design; clearing the right-of-way; laying out the fence; and safety concerns. It describes components including braces and posts, brace designs, gates and materials and tools necessary to build a fence. Detailed descriptions of electric, wire, and wood fences are discussed.

Facilities for Watering Livestock and Wildlife, MTDC 89-1, January 1989. This volume gives an overview of basic concepts, techniques, and equipment used to provide water for livestock and wildlife. These facilities are improvements that collect, transport, store, or provide access to water. Collecting water discusses wells, pumps, windmills, dams, and reservoirs. Transporting water includes information on pumps and piping. Water storage describes reservoirs and storage tanks. The section dealing with access to water facilities describes methods of allowing wildlife and livestock to water without damaging the storage facility.

These volumes can be ordered from:

Society of Range Management
1839 York Street
Denver, Colorado 80206

There is a charge for each volume:

Fences, $10

Facilities for Watering Livestock and Wildlife, $6

Facilities for Handling, Sheltering and Trailing Livestock, $5

Workgroups

Steve Monsen, Chairman, RTEC
USDA Forest Service
Shrub Sciences Laboratory
735 N. 500 E.
Provo, UT 84664

Those interested in participating in the activities of a workgroup should write or call the workgroup chairman.

Information and Publications

Dick Hallman, Chairman, FS
Missoula Technology & Development Center
Bldg. 1, Fort Missoula
Missoula, MT 59801

Plant Materials

Wendall Oaks, Chairman, SCS
Plant Materials Center
1036 Miller St.
Los Lunas, NM 87031

Fire

Phil Range, Chairman, BLM
Boise Interagency Fire Center
3905 Vista Ave.
Boise, ID 83705

Seeding & Planting

Harold Wiedemann, Chairman
Texas Agricultural Experiment Station
Box 2658
Vernon, TX 76384

Seedbed Ecology

(Vacant)

Structures

(Vacant)

Weeds and Weed Management

(Vacant)

Introduction

The Vegetative Rehabilitation and Equipment Workshop was an informal group of range specialists who were concerned with developing and testing equipment and serving as a clearinghouse of information for land managers. The effort to adapt or develop equipment suitable for range seeding began in 1945. The original organization was called the Range Seedling Equipment Committee. In 1975 the group became the Vegetative Rehabilitation & Equipment Workshop (VREW) to better reflect the expanded interests and membership. The USDA Forest Service, the Bureau of Land Management, the Soil Conservation Service, the Bureau of Indian Affairs, as well as State agencies, universities, manufacturers, energy companies, seed suppliers, ranchers, and consultants met to consider harvesting brush and grass seed, evaluate aerial ignition techniques, develop equipment for reclaiming strip-mined land and revegetating disturbed areas in arid climates. The goal of establishing permanent, diverse vegetative cover remained the prime concern of VREW through 1989.

In 1990 the growing role of State and Private resource agencies led to a broader charter for the group. The Rangeland Technology and Equipment Council (RTEC) has been formed to incorporate all federal, state, and private range land managers. The Council will focus on high technology techniques as well as traditional equipment development for solving management problems.

This year's RTEC annual report presents a selection of equipment and techniques reported at the Washington, D.C. meeting by 1991 speakers.

Papers

Fire Effects Information System

William C. Fischer, Research Forester and Team Leader, Intermountain Research Station, Forest Service, U.S. Department of Agriculture, Intermountain Fire Sciences Laboratory, Missoula, Montana

Description of the System

The Fire Effects Information System is a computerized knowledge management system that stores and retrieves state-of-the-knowledge, English-language textual information organzied in an encyclopedic fashion. The design and structure of the system are based on artificial intelligence (AI) concepts, methods, and techniques previously described by Fischer and Wright (1987). Although based on AI technology, the Fire Effects Information System is not an "expert system" but rather a knowledge processor of the document database type (Rauscher 1987, Fischer and Brown 1991). The system was developed and is being implemented by the Forest Service, U.S. Department of Agriculture, at the Intermountain Research Station's Fire Sciences Laboratory in Missoula, Montana. System software was developed in cooperation with the Computer Science Department of the University of Montana, Missoula.

System Components

The Fire Effects Information System consists of three components: the knowledge base, the query program, and the builder program. The knowledge base contains the fire effects and related biological and ecological information that is available to those who access the system. The query program allows access to the knowledge base but does not allow any changes. It is designed for resource managers and resource specialists who are not necessarily computer experts. On-screen prompts and menus guide the operator to the desired information. The builder program is used only by those who are adding to or editing the knowledge base. Because it is the object of the system, the knowledge base is described in more detail below.

The Knowledge Base

The fire effects knowledge base is designed to accept information in three major categories: plant species, ecosystems, and wildlife species. The ecosystem category includes three levels of classification: an ecosystem level, a cover type level, and a habitat type or plant community level. For each category and level, the knowledge base contains state-of-the-knowledge information as text for various predetermined topics for several subject areas. Topics by subject for the plant species category are listed in *table 1*. Fischer (1987), Fischer and Wright, (1987) and Bradley (1990) provide examples of information as it is presented by the system. At present, the knowledge base contains information for 294 plant species (77 trees, 120 shrubs, 68 graminoids, and 29 forbs), 8 wildlife species, and 10 sagebrush cover types. Distribution of plant species according to their occurrence among the 34 Forest and Range Environmental Study ecosystems described by Garrison and others (1977) is presented in *table 2*. The Bureau of Land Management (BLM), U.S. Department of the Interior (USDI), provided initial as well as strong continuing support for knowledge base development.

The present data base contains, consequently, many of the common plant species that occur in Great Basin and southwestern United States rangelands. Prairie and plains grassland species were added to the knowledge base when the National Park Service, also USDI, supported development of a data base for Wind Cave National Park, South Dakota. The initial emphasis on plant species rather than wildlife species reflects the expressed needs of the agencies supporting knowledge base development. This is a logical decision because most fire effects of concern to wildlife managers are secondary effects caused by fire-related changes in wildlife habitat. More emphasis on wildlife species is anticipated during the next several years.

Current Access to the System

The Fire Effects Information System presently resides on a Data General (DG) computer at the Intermountain Fire Sciences Laboratory in Missoula, Montana. A copy of the knowledge base and query also resides on a BLM DG computer at the Boise Interagency Fire Center, Boise, Idaho. BLM personnel access the system at Boise using an IBM-compatible personal computer (PC) with a 1200 band phone modem and terminal emulation/communications software that can emulate a DG 400 terminal. Forest Service personnel access the system at the Fire Sciences Laboratory via the service-wide DG electronic communications system. Other natural resource agencies and institutions may obtain permission to access the system in Missoula provided they have the appropriate PC, modem and DG emulation and communications software.

Operational Implementation

A national operational implementation of the Fire Effects Information System is progressing under the auspices of the National Wildfire Coordinating Group (NWCG). The NWCG consists of members from the Forest Service, Bureau of Land Management, National Park Service, Bureau of Indian Affairs, Fish and Wildlife Service, and the National Association of State Foresters. The purpose of NWCG is to coordinate the development and implementation of products that improve the overall effectiveness of fire management in member agencies.

Two major tasks associated with a national implementation are to provide system access to all interested users and to expand the knowledge base to meet national needs for fire effects information. During the implementation period at least 400 plant species will be added to the system's knowledge base.

Additional information regarding the Fire Effects Information System can be obtained from the Forest Service System Manager, Dave Anderson, Boise Interagency Fire Center, 3905 Vista Avenue, Boise, Idaho 83705-0126 or from the author.

Publications Cited

Bradley, A.F. 1990. *The fire effects information system: a tool for shrub information management.* ***In***: Proceedings - Symposium on Cheatgrass Invasion, Shrub Die-off, and Other Aspects of Shrub Biology and Management, 1989 April 5-7; Las Vegas, NV. General Technical Report INT-276, Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, p. 263-281.

Fischer, W.C. 1987. *The fire effects information system.* **In:** Proceedings of the Symposium on Wildland Fire 2000, 1987 April 27-30; South Lake Tahoe, CA. General Technical Report PSW-101, Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station, p. 128-135.

Fischer, W.C.; Brown, J.K. 1991. *A document database system for managing fire effects knowledge.* The Compiler. (In press).

Fischer, W.C.; Wright, A.H. 1987. *FIRESYS: Using artificial intelligence techniques to build a fire effects information system.* The Compiler. 5(5): 28-35.

Rauscher, H.M. 1987. *Increasing scientific productivity through better knowledge management.* AI Applications. 1(2): 21-31.

Table 1. – *Information contained in the Fire Effects Information System knowledge base for plant species.*

Plant Species Category	**Botanical & Ecological Characteristics**
Species name	General botanical characteristics
Abbreviation	Raunkiaer life form
Synonyms	Regeneration process
Plant code (SCS list of scientific plant names)	Site characteristics
Taxonomy	Successional status
Life form	Seasonal development
Federal legal status	
Other status	**Fire Ecology**
Compiled by and date	Fire ecology or adaptations
Last revised by and date	Lyon-Stickney fire survival strategy
Authorship and citation	
Distribution & Occurrence	**Fire Effects**
General distribution	Immediate fire effect on plant
Ecosystems	Discussion & qualirfication of fire effect
States	Plant response to fire
Administrative units	Discussion & qualification of plant response
BLM phsiographic regions	Fire management considerations
Kuchler plant associations	
SAF cover types	**Fire Case Study**
Habitat types and plant communities	Case study name
Value & Use	Reference
Wood products value	Season-severity class
Importance to livestock and wildlife	Study location
Palatability	Preburn vegetation
Food value	Target species phenological state
Cover value	Site description
Value for rehabilitation of disturbed sites	Fire description
Other uses and values	Fire effects on target species
Management considerations	Fire management implications
	References

Table 2. – ***Number of plant species and life forms by ecosystem in the Fire Effects I nformation System (as of 31 January 1991).***

Ecosystem	Trees	Shrubs	Graminoids	Forbs	Total
Forest & Woodland Ecosystems					
White-red-jack pine	9	8	3	5	**25**
Spruce-fir	8	11	1	6	**26**
Longleaf-slash pine	2	1	1	1	**5**
Loblolly-shortleaf pine	4	2	2	2	**10**
Oak-pine	5	3	2	1	**11**
Oak-hickory	17	18	19	7	**61**
Oak-gum-cypress	7	1	1	—	**9**
Elm-ash-cottonwood	18	20	29	3	**70**
Maple-beech-birch	10	8	2	4	**24**
Aspen-birch	12	7	4	3	**26**
Douglas-fir	41	50	35	14	**140**
Ponderosa pine	56	71	55	18	**200**
Western white pine	12	15	—	5	**32**
Fir-spruce	39	43	28	18	**128**
Hemlock-Sitka spruce	13	29	1	3	**46**
Larch	11	17	2	5	**35**
Lodgepole pine	31	36	15	10	**92**
Redwood	17	18	—	5	**40**
Western hardwoods	48	38	10	6	**102**
Shrubland Ecosystems					
Sagebrush	34	63	54	17	**168**
Desert shrub	20	55	37	8	**120**
Shinnery	4	6	3	1	**14**
Texas savanna	13	9	13	1	**36**
Southwestern shrubsteppe	11	9	9	2	**31**
Chaparral-mountain shrub	44	69	49	10	**172**
Pinyon-juniper	39	69	54	13	**175**
Grassland Ecosystems					
Mountain grasslands	17	39	48	16	**120**
Mountain meadows	1	6	—	4	**11**
Plains grasslands	25	34	51	11	**121**
Prairie	14	18	32	6	**70**
Desert grasslands	16	40	29	7	**92**
Wet grasslands	2	1	4	—	**7**
Annual Grasslands	1	—	3	—	**4**
Alpine Ecosystems					
Alpine	4	14	7	5	**30**

Appendix:

Plant species, cover types, and wildlife species presently represented in the Fire Effects Information System.

Tree Species

Abies concolor, white fir
Abies lasiocarpa, subalpine fir — In preparation
Acacia greggii, catclaw acacia
Acer circinatum, vine maple
Acer glabrum, Rocky Mountain maple
Acer grandidentatum, bigtooth maple
Acer macrophyllum, bigleaf maple
Acer negundo, boxelder
Alnus incana ssp. tenuifolia (A. tenuifolia), thinleaf alder
Alnus rhombifolia, white alder
Alnus rubra, red alder
Alnus viridis ssp. sinuata, Sitka alder
Arbutus menziesii, Pacific madrone
Arbutus texana, Texas madrone
Betula occidentalis, western birch, water birch
Castanopsis chrysophylla, golden chinkapin
Celtis occidentalis, hackberry
Celtis reticulata, netleaf hackberry
Cercocarpus ledifolius, curlleaf mountain-mahogany
Cercocarpus montanus, true mountain-mahogany
Chamaecyparis lawsoniana, Port-Orford-cedar
Chilopsis linearis, desert willow
Cornus (stolonifera) sericea, red-oiser dogwood
Cowania mexicana var. stansburiana, Stansbury cliffrose
Fraxinus pennsylvanica, green ash
Juglans microcarpa, little walnut
Juniperus communis, common juniper
Juniperus deppeana, alligator juniper
Juniperus monosperma, oneseed juniper
Juniperus occidentalis, western juniper
Juniperus osteosperma, Utah juniper
Juniperus scopulorum, Rocky Mountain juniper
Larix occidentalis, western larch
Lithocarpus densiflora, tanoak
Pinus albicaulis, whitebark pine
Pinus aristata, Rocky Mountain bristlecone pine
Pinus balfouriana, foxtail pine
Pinus edulis, true pinyon
Pinus flexilis, limber pine
Pinus longaeva, Great Basin bristlecone pine
Pinus monophylla, singleleaf Pinyon
Pinus ponderosa var. scopulorum, interior (Black Hills) ponderosa pine
Populus angustifolia, narrowleaf cottonwood
Populus balsamifera, balsam poplar
Populus deltoides, eastern/plains cottonwood
Populus fremontii, Fremont cottonwood
Populus tremuloides, aspen
Populus trichocarpa, black cottonwood
Prosòpis glandulosa var. glandulosa, honey mesquite
Prosopis glandulosa var. torreyana, western honey mesquite
Proscopis pubescens, screwbean mesquite
Prosopis velutina, velvet mesquite
Prunus americana, American plum
Prunus ilicifolia, hollyleaf cherry
Prunus pensylvanica, pin cherry
Prunus virginiana, chokecherry
Quercus chrysolepis, canyon live oak
Quercus gambelii, Gambel oak
Quercus havardii, sand shinnery oak — In preparation
Quercus marcrocarpa, bur oak
Quercus muehlenbergii, chinquapin oak — In preparation
Quercus turbinella, turbinella oak
Quercus wislizenii, interior live oak
Rhododendron macrophyllum, Pacific rhododendron
Rhus glabra, smooth sumac
Salix amygdaloides, peachleaf willow
Salix exigua, sandbar willow
Salix lasiandra, Pacific willow
Salix lutea (S. rigida var. watsonii), yellow willow
Salix scouleriana, Scouler willow
Sambucus cerulea, blue elderberry
Sambucus racemosa ssp. pubens, red or black elderberry
Sapindus saponaria var. drummondii, western soapberry
Sophora secundiflora, mescalbean sophora
Taxus brevifolia, Pacific yew
Ungnadia speciosa, Mexican buckeye
Vaccinium arboreum, tree sparkleberry
Yucca brevifolia, Joshua tree
Yucca elata, soaptree yucca
Yucca schidigera, Mohave yucca

Shrub Species

Acacia constricta, whitethorn acacia
Adenostoma fasciculatum, chamise
Agave lechuguilla, lechuguilla
Ambrosia (Franseria) deltoidea, triangle bursage
Ambrosia (Franseria) dumosa, white bursage
Amelanchier alnifolia, Saskatoon serviceberry
Amelanchier utahensis, Utah serviceberry
Amorpha canescens, leadplant
Arctostaphylos pungens, pointleaf manzanita
Arctostaphylos uva-ursi, *bearberry*, kinnikinnick — In preparation
Artemisia abrotanum, oldman wormwood
Artemisia arbuscula ssp. arbuscula, gray low sagebrush
Artemisia arbuscula ssp. thermopola, hotsprings sagebrush
Artemisia argilosa, coaltown sagebrush
Artemisia bigelovii, Bigelow sagebrush
Artemisia cana ssp. bolanderi, Bolander silver sagebrush
Artemisia cana ssp. cana, plains silver sagebrush
Artemisia cana ssp. viscidula, mountain silver sagebrush

Artemisia filifolia, sand sagebrush
Artemisia frigida, fringed sagebrush
Artemisia longiloba, alkali sagebrush
Artemisia nova, black sagebrush
Artemisia papposa, Owyhee sagebrush
Artemisia pedatifida, birdfoot sagebrush
Artemisia pygmaea, pygmy sagebrush
Artemisia rigida, stiff sagebrush
Artemisia spinescens, budsage
Artemisia tridentata ssp. tridentata, basin big sagebrush
Artemisia tridentata ssp. vaseyana, mountain big sagebrush
Artemisia tridentata ssp. wyomingensis, Wyoming big sagebrush
Artemisia tripartita ssp. rupicola, Wyoming threetip sagebrush
Artemisia tripartita ssp. tripartita, tall threetip sagebrush
Atriplex canescens, fourwing saltbush
Atriplex confertifolia, shadscale
Atriplex gardneri, saltsage
Betula glandulosa, bog birch
Ceanothus cuneatus, wedgeleaf ceanothus
Ceanothus greggii, desert ceanothus
Ceanothus integerrimus, deerbrush
Ceanothus leucodermis, chaparral whitethorn
Ceanothus sanguineus, redstem ceanothus
Ceanothus velutinus, snowbrush ceanothus
Ceratoides lanata, winterfat
Chrysothamnus nauseosus, rubber rabbitbrush
Chrysothamnus viscidiflorus, low rabbitbrush
Cornus canadensis, bunchberry
Coleogyne ramosissima, blackbrush
Ephedra nevadensis, Nevada ephedra
Ephedra viridis, green ephedra
Fallugia paradoxa, Apache plume
Flourensia cernua, tarbush
Gaultheria shallon, salal
Garrya wrightii, Wright silktassel
Grayia brandegei, spineless hopsage
Grayia spinosa, spiny hopsage
Gutierrezia sarothrae, broom snakeweed
Heteromeles arbutifolia, toyon
Holodiscus discolor, oceanspray
Holodiscus dumosus, bush oceanspray
Juniperus horizontalis, creeping juniper
Larrea tridentata, creosotebush
Leptodactylon pungens, prickly phlox
Mahonia (Berberis) nervosa, dwarf Oregon grape
Mahonia (Berberis) trifoliolata, agarito
Mimosa biuncifera, catclaw mimosa
Opuntia polyacantha, plains pricklypear
Philadelphus lewisii, mockorange
Potentilla fruticosa, shrubby cinquefoil
Prunus andersoni, desert peach
Purshia glandulosa, desert bitterbrush
Purshia tridentata, antelope bitterbrush
Quercus dumosa, scrub oak
Rhamnus californica, California coffeeberry
Rhus aromatica, fragrant sumac
Rhus microphylla, littleleaf sumac
Rhus trilobata, skunkbush sumac
Ribes americanum, American black currant
Ribes aureum, golden currant
Ribes cereum, wax currant
Ribes lacustre, swamp currant
Ribes montigenum, gooseberry currant
Ribes odoratum, buffalo currant
Ribes setosum, bristly gooseberry
Ribes velutinum, desert gooseberry
Rosa acicularis, prickly rose
Rubus discolor, Himalayan blackberry
Rubus idaeus, red raspberry
Rubus laciniatus, evergreen blackberry
Rubus parviflorus, thimbleberry
Rubus spectabilis, salmonberry
Rubus ursinus, trailing blackberry
Salix lemmonii, Lemmons willow
Salvia mellifera, black sage
Sarcobatus baileyi, Bailey greasewood
Sarcobatus vermiculatus, black greasewood
Symphoricarpos longiflorus, desert snowberry
Symphoricarpos oreophilus, mountain snowberry
Tetradymia canescens, gray horsebrush
Tetradymia glabrata, littleleaf horsebrush
Tetradymia nuttallii, Nuttall horsebrush
Tetradymia spinosa, spiny horsebrush
Toxicodendron rydbergii, western poison ivy
Toxicodendron diversilobium, poison oak
Vaccinium angustifolium, low sweet blueberry — In preparation
Vaccinium caespitosum, dwarf huckleberry
Vaccinium globulare, globe huckleberry
Vaccinium membranaceum, blue huckleberry
Vaccinium myrsinites, ground blueberry
Vaccinium myrtilloides, velvetleaf blueberry
Vaccinium myrtillus, dwarf bilberry
Vaccinium occidentale, western huckleberry
Vaccinium ovalifolium, ovalleaf huckleberry
Vaccinium ovatum, evergreen huckleberry
Vaccinium parvifolium, red huckleberry
Vaccinium scoparium, grouse whortleberry
Vaccinium vacillians, lowbush blueberry — In preparation
Vaccinium vitis-idaea, mountain cranberry — In preparation
Yucca baccata, banana yucca
Yucca glauca, soapweed yucca
Yucca whipplei ssp. caespitosa, Our Lord's candle
Yucca whipplei ssp intermedia, Our Lord's candle
Yucca whipplei ssp parishii, chaparral yucca
Yucca whipplei ssp. percursa, Our Lord's candle
Yucca whipplei ssp. whipplei, Our Lord's candle

Graminoid Species

Agropyron cristatum (A. pectiniforme), fairway wheatgrass
Agropyron desertorum, standard wheatgrass
Andropogon gerardii var. gerardii, big bluestem
Andropogon gerardii var. paucipilus (A. hallii), sand bluestem
Aristida purpurea (A. longiseta), red three-awn
Bothriochloa (Andropogon) barbinodis, cane bluestem
Bouteloua barbata var. barbata, six-weeks grama
Bouteloua curtipendula, sideoats grama
Bouteloua eriopoda, black grama
Bouteloua gracilis, blue grama
Bouteloua hirsuta, hairy grama
Bromus carinatus, California brome
Bromus inermis, smooth brome
Bromus japonicus, Japanese brome
Bromus marginatus, mountain brome
Bromus mollis, soft chess
Bromus rubens, red brome
Bromus tectorum, cheatgrass
Buchloe dactyloides, buffalograss
Calomovilfa longifolia, prairie sandreed
Carex heliophila, sun sedge
Danthonia intermedia, timber oatgrass
Danthonia spicata, poverty oatgrass
Danthonia unispicata, onespike danthonia
Distichlis spicata var. stricta, inland saltgrass
Elymus canadensis, Canada wildrye
Elymus elymoides, (Sitanion hystrix), bottlebrush squirreltail
Elymus glaucus, blue wildrye
Elymus *lanceolatus, (Agropyron dasystachyum, A.elmeri, A. riparium)*, thickspike wheatgrass
Festuca idahoensis, Idaho fescue
Festuca scabrella, rough fescue
Festuca thurberi, Thurber fescue
Hilaria belangeri, curly mesquite
Hilaria jamesii, galleta
Hilaria mutica, tobosa
Hilaria rigida, big galleta
Koeleria cristata, prairie junegrass
Leucopoa kingii (Hesperchloa kingii), spike fescue
Leymus (Elymus) ambiguus, Colorado wildrye
Leymus (Elymus) cinereus, basin wildrye
Leymus (Elymus) innovatus, boreal wildrye
Leymus (Elymus) salinus, Salina wildrye
Muhlenbergia cuspidata, plains muhly, Stonyhills muhly
Muhlenbergia porteri, bush muhly
Muhlenbergia racemosa, green muhly
Muhlenbergia richardsonis, mat muhly
Oryzopsis hymenoides, Indian ricegrass
Pascopyrum (Agropyron) smithii, western wheatgrass
Poa arida, plains bluegrass
Poa cusickii, Cusick bluegrass
Poa fendleriana, Fendler bluegrass
Poa secunda, (P.ampla; P.canbyi; P. juncifolia; P.nevadensis; P.sandbergii), Sandberg bluegrass
Psathyrostachys juncea (Elymus junceus), Russian wildrye
Pseudoroegneria spicata (Agropyron spicatum; A.inerme), bluebunch wheatgrass
Schizachyrium (Andropogon) scoparium, little bluestem
Sporobolus airoides, alkali sacaton
Sporobolus asper, tall dropseed
Sporobolus cryptandrus, sand dropseed
Sporobolus flexuosus, mesa dropseed
Stipa columbiana, Columbia needlegrass
Stipa comata, needle-and-thread grass
Stipa lettermanii, Letterman needlegrass
Stipa thurberiana, Thurber needlegrass
Stipa viridula, green needlegrass
Taeniatherum caput-medusae, medusahead
Vulpia (Festuca) microstachys, small fescue
Vulpia myuros (Festuca megalura), foxtail fescue
Vulpia (Festuca) octoflora, sixweeks fescue

Forb Species

Achillea millefolium, western yarrow
Actaea rubra, red baneberry
Artemisa campestris, western sagebrush
Artemisia dracunculus, tarragon
Artemisia ludoviciana, Louisiana sagewort
Balsamorhiza hookeri, Hooker balsamroot
Balsamorhiza sagittata, arrowleaf balsamroot
Centaurea diffusa, diffuse knapweed
Centaurea maculosa, spotted knapweed
Centaurea solstitialis, yellow starthistle
Corydalis sempervirens, pink corydalis
Darlingtonia californica, California pitcher plant
Descurainia pinnata, pinnate tansymustard
Descurainia sophia, flixweed tansymustard
Erythronium grandiflorum, glacier lily
Goodyera repens, northern rattlesnake plantain
Hedysarum alpinum var. americanum, American sweetvetch
Lycopodium obscurum, ground pine
Polystichum munitum, swordfern
Potentilla glandulosa, sticky cinquefoil
Potentilla hippiana, horse cinquefoil
Potentilla newberryi, Newberry cinquefoil
Pteridium aquilium, bracken fern
Ranunculus glaberrimus, sagebrush buttercup
Selaginella densa, little cubmoss
Sisymbrium altissimum, tumblemustard
Sisymbrium linifolium, flaxleaf plainsmustard
Spaeralcea coccinea, scarlet globemallow
Xerophyllum tenax, beargrass

Cover Types

Artemisia arbuscula ssp. arbuscula C.T., gray low sagebrush cover type
Artemisia arbuscula ssp. thermopola C.T., hotsprings sagebrush cover type
Artemisia cana ssp. bolanderi C.T., bolanderi silver sagebrush cover type
Artemisia cana ssp. cana C.T., plains silver sagebrush cover type
Artemisia cana ssp. viscidula C.T., mountain silver sagebrush cover type
Artemisia filifolia C.T., sand sagebrush cover type
Artemisia frigida C.T., fringed sagebrush cover type
Artemisia nova C.T., black sagebrush cover type
Artemisia tridentata ssp. tridentata C.T., basin big sagebrush cover type
Artemisia tridentata ssp. wyomingensis C.T., Wyoming big sagebrush cover type

Wildlife Species

Amphibians & Reptiles

Ambystoma macrodactylum ssp. krausei, northern long-toes salamander
Crotalus viridis, western rattlesnake — In preparation
Sceloporus graciosus, sagebrush lizard — In preparation
Scophiopus intermontanus, Great Basin spadefoot toad

Birds

Aquila chrysaetos, golden eagle — In preparation
Athene cunicularia, burrowing owl
Buteo regalis, ferruginous hawk — In preparation
Centrocercus urophasianus, sage grouse
Falco mexicanus, prairie falcon — In preparation

Mammals

Antilocapra americana, pronghorn
Lepus californicus, black-tailed jackrabbit
Perognathus parvus, Great Basin pocket mouse
Spermophilus townsendii, Townsend's ground squirrel

Aerial Ignition Techology and Expert Systems

Henry A. Wright Texas Tech University, Lubbock, Texas

We burn 10,000 to 20,000 acres of chained redberry juniper (*Juniperus pinchoti*) each year. Redberry juniper is a sprouting species. Thus, our burns generally contain a mixture of grass, dead brush and green juniper trees that are 5 to 10 feet tall. In order for us to burn this much acreage in moderately rough country, we began using the helitorch method of burning in 1983.

Initially, our ignition system consisted of an 80 amp igniter in a 2-inch bell housing where jellied gasoline was pumped out. The jell fell in large globs about every 100 feet. Moreover, we emptied a barrel of jell in 5 to 10 minutes. For grassland-brush mixtures we needed a delivery system that would break up the jell into small ignited particles and be able to stay in the air for longer periods of time.

To accomplish our objective a stainless steel screen was welded to the original bell housing with a valve to control rate of flow. This screen area served as a wick to ignite five streams of jell from 3/16-inch orifices that were mounted with a separate control valve about 1-inch behind the stainless steel screen. To control pressure of jell flow, a backfeed was added to allow jell to flow back to the top of the barrel. Thus, less jell was wasted. This mechanism proved to be a very efficient ignition system and allowed us to remain airborn for 25 minutes per 55-gallon load.

Flying at 75 to 100 feet above the ground, our swath width is 40 to 45 feet. We call it a "rain-drop system" because of the raindrop pattern of ignited jell. We currently use this ignition system to burn 400-foot blacklines together with hand crews, depending on weather conditions. For headfires, we only use the helitorch because it is more effective than hand ignition (burns hotter) and allows us access to rough country. Generally we fly 100- to 200-yard strips, but fly along the base of hills when possible.

We mix 6 pounds of alumijel per 55-gallon drum of unleaded gas to make our jell. Four people are needed to load each barrel. We always use the front-load method because it is safer. Moreover, the pilot can see everyone and direct them as necessary. While igniting the brush, an observer is permitted to be with the pilot to direct him where to fly and help keep the fire within the lines prepared. The observer should be experienced in fire behavior as well as be knowledgeable about the unit to be burned (boundaries, power lines, oil tanks, etc.)

Chained redberry juniper is a highly volatile fuel type. Thus, weather and fuel data are taken every 30 minutes to avoid burning when spot fires may occur. Hand burning is used when conditions are marginal for burning blacklines (i.e., relative humidity 30-50%; air temperature 50 to 65 degrees F, wind 6 to 10 mph). Nighttime is safer than daytime (i.e., we would burn with relative humidity as low as 30% during nighttime, but in the daytime it must be at least 40%). The helicopter is used to burn blacklines when the relative humidity is above 50%, temperature is below 50 degrees F, and wind speed is less than 6 mph. Headfires are conducted only in the daytime when air temperature is 65 to 80 degrees F, relative humidity is 25 to 40%, and wind speed is 8 to 15 mph. Green juniper moisture content must be below 80%. Generally it is between 60% (very dry) and 80%.

We are developing an Expert System to burn volatile fuels. Using a laptop computer, we punch in air temperature, relative humidity, wind speed, green juniper fuel moisture content, day or nighttime, roughness of topography, and fuel load to advise "burning" or "no burning". A confidence level of risk and a narrative is given with each burning or no burning answer. In our judgement the Expert System is conservative (safe) and especially helpful to newly trained peole who are learning the art of prescribed burning.

Overall, we are very satisfied with the ignition system for jellied gasoline. This year, instead of the sling, we are building a fuel tank that will be tightened snug to the skids of the helicopter but still ejectable. Remote controls for flow valves of the jellied gasoline are essential because the flow rates need to be adjusted during flight depending on the wind direction. We generally fly 60 knots/hr with the wind and 40 knots/hr against the wind. We burn about 1400 acres/hour (two barrels of jellied gasoline) on headfires. Two to three miles of blackline can be burned per hour with the helitorch, whereas this is usally a 5 to 6-hour job with a 15-person hand crew.

Cost to burn blacklines has not been established. Cost for the helitorch to burn headfires is $1.25 per acre, provided that we have a minimum of 10,000 acres to burn.

Agricultural Aircraft in BLM Fire Suppression

Ron Hanks, Aviation Specialist, USDI Bureau of Land Management, Boise, Idaho

Since the early 1950's the evolution of aerial retardant aircraft in the federal firefighting inventory has evolved toward increasingly larger multi-engine aircraft. As a result today's fleet of large air tankers requires long paved runways, large loading ramps, wide aprons, and taxiways capable of supporting tremendous wheel weights. This situation created a void in the air attack system because airports meeting these requirements were often long distances from the fire line. Heretofore, we have attempted to fill this void with helicopters using a variety of fixed tanks and sling mounted buckets. While helicopter operations have been successful they are expensive and require considerable amounts of government support equipment and personnel.

In 1984, the Bureau of Land Management formally began to evaluate the use of commercial agricultural application aircraft "crop-dusters" in the fire suppression program. It was hoped these aircrat could be used to fill the void at significantly less cost. This has proven to be the case.

Over the past thirty years considerable advancements have occurred in agricultural aircraft. Along with improved airframe design and construction, modern agricultural application aircraft use turbine engines, and improved tanking and gating systems. Agricultural aircraft can operate from the most rudimentary airports and often operate from non-airport sites. Agricultural aircraft operators are equipped and accustomed to handling toxic and caustic chemicals such as herbicides and insecticides. As a result they have the ground mixing and loading equipment and personnel eminently qualified to support the aerial delivery of firefighting chemicals. The small size and good maneuverability of the aircraft coupled with reliable powerplants enable many models to deliver an average of 400 (U.S.) gallons of fire retardant into "tight" spots with minimal need for any government support personnel or equipment.

In summary, BLM has found that substantial aerial fire fighting capability is presently available from agricultural aircraft operators. The services of these vendors are readily available to serve most of our users. They can be used and managed effectively by local fire managers, and are very cost effective.

The Native Plant Issue

W. Curtis Sharp, National Plant Materials Specialist, USDA Soil Conservation Service, Washington, DC

There are no doubt, many native plant issues. This paper will address only one. First, however, a definition of native plants needs to be established. The definition I will use is: "A plant that evolved within an identifiable ecological zone", such as those proposed by James M. Omernik, in Ecoregions of the U.S., H. L. Shantz, Natural Vegetation or A.W. Kuchler in Potential Natural Vegetation or others. It is presented here only as a point of reference for my comments. As my remarks continue, you will see the need to define 'ecological zones' also.

The issue I would like to discuss is: Availability of native plants to meet re-vegetation needs.The following comments relative to the availability of native plants is based on the assumption that the use of native plants for re-vegetating alterations to plant communities is highly desirable on both public or private lands, and is likely to increase. Such sites include construction sites, government supported conservation plantings, degraded rangeland, plantings to re-establish plant diversity, wildlife habitat improvement plantings and re-vegetation following fires.

Regardless of the desirability of using native plants for re-vegetation purposes, their use will be no greater than their availability. The demand for native plants generally falls into two categories:

A. Large scale demands, such as rangeland re-vegetation, government supported conservation plantings, or plantings following major fires. Such plantings would normally exceed 10 acres and may be several hundred acres.

These needs are generally being met, or should be met by commercial production of cultivars of natives, developed by the Soil Conservation Service or others. This material will be characterized by broadly based ecotypes and adptable over many ecological zones. The number of ecotypes and/or species available at any one time on the commercial market will be small, however.

B. The demand for native plants to re-vegetate what I will call 'micro-sites'. Micro-sites might consist of less than one or up to a few acres.

The demand for plant materials for these sites is characterized by:

1) the desire of the land owner or manager to duplicate as nearly as possible the native vegetation;
2) the potential of thousands of micro-sites collectively requiring a very large number of ecotypes for re-vegetation purposes, and
3) the cost of having ecotypes available on a micro-site by micro-site basis is very high relative to the cost of commercially available plant materials. There is, nevertheless, a need for a cost effective and continuously available supply of a large number of native ecotypes for re-vegetating micro-sites.

How can this be done? The following is offered as one approach.

Public and private groups with an interest and/or responsibility for maintaining native plant diversity on public and private lands, and for technology development, to:

1. Agree on a set of ecological zones,
2. Identify and collect ecotypes within ecological zones that are representative of a selected set of species,
3. Develop the technology for propagating these species,
4. Produce small quantities,
5. Deposit this material into a bank of 'ecological zone ecotypes', and maintain,
6. Make small amounts from the bank available to public and private groups for increasing the ecotype to meet the immediate need, logically by a commercial firm, or for actually making micro-site plantings, if the quantity needed is very small. At the time a withdrawal is made arrangements to re-deposit that which was removed from the bank would need to be made.

The bank would be owned and managed by involved agencies and private groups, sharing the cost. Plants in the bank would not logically be maintained in the commercial trade, unless an ecotype showed unusual adaptation to many ecological zones.

The six steps above may seem like a very large task. However, many of the pieces to make it a reality exist today. The major task will be to bring them together in a cooperative spirit and coordinate them into a functioning system. The Soil Conservation Service has many of the required resources and facilities in place within their Plant Materials Center Program and are willing to assist in the coordination.

National Park Service Native Plant Needs

William R. Beavers, National Technical Advisor for Plant Materials, USDI National Park Service, Denver, Colorado

The National Park System of the United States comprises 356 areas covering almost 80 million acres in 49 states, the District of Columbia, America Samoa, Guam, Puerto Rico, Saipan, and the Virgin Islands. These areas are of such national significance as to be afforded protection by various acts of Congress.

After the establishment orf Yellowstone National Park on March 18, 1872, a worldwide park movement began that has resulted in more than 100 nations setting aside 1,200 national parks for public enjoyment and the preservation of natural, cultural, or historical resources.

The diversity of the National Park system is reflected in the variety of the park unit titles. Congress has used more than 20 different designations in adding areas to the National Park System. These titles are usually descriptive: seashore, lakeshore, historic site, battlefield, and recreation area, for example. The designations have not always been used consistently, but they reflect certain precedents that have been followed by Congress. The title of national park has traditionally been reserved for the most spectacular natural areas with a wide variety of features. All these areas are managed by the National Park Service in accordance with specific legislative mandates set forth by Congress. Key management requirements for all park units are that they must provide for public use in such a way that will leave their resources "unimpaired for the enjoyment of future generations."

Achieving this management objective of preserving resources while providing for public enjoyment is a delicate balancing act for the park administrator. Revegetation and reclamation activites present special problems when trying to maintain native plant populations in areas impacted by visitor facilities. When preserving natural resources National Park Service policy seeks to perpetuate native plant life as part of the natural ecosystems. To the extent possible, plantings in park units consist of species that are native to the park or that are historically appropriate for the event commemorated. To this end a cooperative agreement between the National Park Service and the Soil Conservation Service was developed in 1989. This cooperative Plant Materials Program seeks to draw upon the strengths of the two federal agencies in the development, testing, and establishment of native species for disturbed sites within National Park Service units.

The plant materials program between the two agencies initially focused on development of native plants for the revegetation of areas disturbed by road construction. Reconstruction of park roads is handled through monies allocated to the National Park Service from the Federal Highway Administration and is obtained from the National Highway Trust Fund. The National Park Service receives over 60 million dollars annually which is allocated to construction or repair of approximately 200 miles of road out of the 4800 miles of paved roads contained within the park system. The park roads program between the National Park Service and the Federal Highway Administration is the ideal starting point for the plant material program. Since advanced scheduling and funding appropriations are critical to the timely success of this program, the park roads program assures that all plant materials projects will be adequately funded and that sufficient lead time will be available to complete plant production schedules.

Presently, the National Park Service and the Soil Conservation Service have developed plant materials agreements for 20 park road projects with an annual budget exceeding half a million dollars. In addition, a park wide plant materials program is under development within the Rocky Mountain Region of the National Park Service and should be extended to most parks within the next four years. Within the next five years the plant materials program can be expected to grow to an annual budget exceeding 1.5 million dollars that will address plant materials needs in 40 park units. Native plant needs will range from cool to warm season grasses, to a variety of shrubs and half shrubs, to trees ranging from the Pacific Northwest to the forests of the deep south. The majority of these plants will not be available to the National Park Service through commercial suppliers. Basic information about the development and growth habits of these plants is presently lacking. The plant program and information generated over the coming years will add to the information base and will help develop park indigenous species that are locally adaptive. In addition, this program will provide the needed reclamation technologies to develop successful revegetation techniques in reestablishing these native park species. The National Park Service feels that its association with the Soil Conservation Service will be most helpful in the understanding and development of native plants.

Soil Conservation Service Plant Materials Role in Developing Native Plants for Parks

Wendell G. Hassel, Plant Materials Technical Advisor to the National Park Service, USDA Soil Conservation Service, Denver, Colorado

The National Park Service (NPS) plant materials needs for native species and establishment methods complement on-going revegetation programs at several Soil Conservation Service (SCS) Plant Materials Centers (PMC). The agencies felt a cooperative effort could:

1. Promote better resource management and protection.
2. Improve public service.
3. Accelerate the development of needed native plants.
4. Advance the state-of-the-art for reclamation and revegetation.

The SCS has been providing plant materials and technical assistance to land managers over the past fifty years. Specialized vegetation and techniques required are not always available. The SCS established 26 PMCs throughout the United States to develop plants and technology to meet these needs.

Networking together centers accomplish national and local objectives. They are ecologicaly located to provide service to a given region. Each center has facilities and specialized equipment to handle a variety of native seed and plants operations needed in plant propagation and testing. The centers cooperate and utilize expertise developed by Agricultural Research Service, Forest Service, State Experiment Stations, and other research institutions. The SCS Plant Materials program is also unique in working relation with seed growers and the commercial seed industry across the United States.

Prior to March 14, 1989, when SCS and NPS formally signed a memorandum of understanding, four centers were conducting plant materials work with specific parks. In 1986, Yellowstone National Park had a four year agreement with the Bridger, Montana PMC, to collect, test, and develop plant materials for various road reclamation projects and the Bridger PMC was also working with Glacier National Park in 1987 to develope plant materials.

Corvallis Oregon PMC started working with Olympic in 1987 and the Meeker and Lockeford centers initiated long term agreements with Grand Teton and Yosemite National Parks respectively in 1988.

To date the cooperative plant materials projects have focused on road related revegetation work. Fifteen agreements have been developed under the new pilot program. However, most of these projects represent relatively small acreages. They vary in size from 10 to 120 acres. However, the technology and plant materials can be applied to adjacent areas.

Nine new cooperative agreements were completed in fiscal year 1990. These agreements include working with a total of 140 new indigenous plant species at seven PMC's shown below:

Plant Materials Agreements Established - FY '90

Park	SCS Plant Center	Years	No. Species
Bryce Canyon, UT	Meeker, CO	1990-96	9
Chickasaw, OK	Knox City, TX	1990-9	10
Cumberland Gap, KY	Beltsville, MD	1990-95	34
Grand Canyuon, AZ	Los Lunas, NM	1990-94	15
Great Smoky Mtns., TN	Quicksand, KY	1990-94	18
Mesa Verde, CO	Meeker, CO	1990-95	17
Mount Rainier, WA	Corvallis, OR	1990-95	14
Natchez Trace, MS	Coffeeville, MS	1990-94	15
Wupatki, AZ	Los Lunas, NM	1990-93	6

Eight new plant materials agreements are scheduled to be established in fiscal year 1991 as shown below:

Plant Materials Agreements scheduled - FY '91

Park	SCS Plant Center
Agate Fossil Beds, NE	Manhattan, KS
Assateague Island, MD	Cape May, NJ
Cumberland Gap, KY	Beltsville, MD
Gateway, NY	Cape May, NJ
Grand Teton, WY	Meeker, CO
Lake Mead, NV	Tucson, AZ
Lake Meredith, TX	Knox City, TX
Mount Rainier, WA	Corvallis, OR

The NPS Plant Materials program can generally be grouped into four main activities:

1. Seeds are collected within the parks to preserve the unique characteristics of the original plant genetic diversity.

2. Seed and plants are grown and reproduced at centers located with similar climatic conditions.

3. New technology is often needed to reproduce and grow these plants. New techniques are also tested to successfully establish and use the new species.

4. And finally quality seed of native germplasm along with the needed technology for establishment are returned to the park for use by resource managers.

In most parks, it is extremely important that native plant materials appropriate to an area be used for restoration work. If possible, it is desireable to restore the vegetation that was previously present before disturbance. Where disturbance is severe, restoration may have to begin at a lower successional stage and pioneer species considered.

Some of the options park managers use to revegetate a site with native species are:

1. Topsoiling - grade back a thin layer of topsoil with seed and duff; then respread over distrubed area after construction is completed.

2. Collection on site - collect the seed and/or plants on or near the site to be disturbed; then replant on site.

3. Reproduction of indigenous plants - collect seed of park indigenous plants and reproduce plants or seeds. The seed, on generation from original stock, is returned to the park for revegetation purposes.

It is proposed by some that preservation of genetic integrity (genetic resources) is the preservation of not only the full range of genotypes but also the natural proportions of and the natural interactions between genotypes. The interpretation and practical application of this policy could be very difficult within some plant communities. The MPS has several task force committees working on how this policy will apply.

Method of pollination, seed dispersal and plant longevity effect the common gene pool of a species. In working with parks, general guidelines are suggested for seed collection where specific species information is not available:

1. Collect ecotypes having approximately the same flowering time,

2. Collect where site conditions are similar and ecotypes are not isolated by geographic or vegetative features.

3. Collect ecotypes within less than 600 to 1200 feet elevational range.

There are several positive spin-offs from this program. Some of the materials being tested will have application to areas outside of park lands and new technology is being developed. For example, we are working with several other research agencies on long term seed storage of flowering dogwood (Cornus florida) for preservation from Anthracnose fungal disease; developing plant propagation methods for greenleaf manzanita (Arctostaphylos patula), and seed production cultural practices for grassleaf goldenaster (Corylposis major). However, one of the biggest benefits is the interchange of new ideas and technology between agencies.

Developing Native Plants for Big Bend National Park

James Alderson, Plant Materials Specialist, Soil Conservation Service, Temple, Texas

You have heard Curtis, Rocky and Wendell explain the needs, thoughts and concerns that convinced the Soil Conservation Service (SCS) and the National Park Service (NPS) to nationally recognize, support and encourage individual national parks and Plant Materials Centers (PMCs) to work together and realize some common objectives.

From the agenda, it is obvious that others besides the NPS need native plant materials and I am sure there are some stories to tell about cooperation between agencies in those efforts as well.

You have just heard the what and why of the overall NPS/SCS cooperative effort, and now I will tell you some of the when, where and how of a local agreement entered into under the national agreements. Mark will tell you of another.

In February of 1989, personnel from the James E. "Bud" Smith PMC at Knox City, Texas, and the NPS Denver Service Center met at Big Bend National Park (BBNP) to learn of the park's plans for road renovations and associated vegetative needs for erosion control and stabilization of road shoulders. Texas Parks and Wildlife Department was present as well because of similar needs on an adjacent state park.

We spent a day driving the roads scheduled for resurfacing. Along the way, it was obvious there are four distinct vegetative zones within the park. Species of plants vary from zone to zone because of the different soils, elevations, slope, exposures and rainfall but there are a few species common to all four zones. Part of the objective as we toured was to locate adequate colonies of specific species to make harvesting of seed effective and efficient.

The plan that evolved from this strategy session called for PMC personnel to collect seed of 8 species of grasses and forbs which would be taken to the PMC and planted in seed increase fields in 1989, 1990 and 1991. We reasoned that it might take 3 years to collect enough seed to plant large enough seed production fields for the volume of seed needed to treat 22 miles of road shoulders. Six species were selected as the basic components of a mixture suitable to the entire road section. The species are alkali sacaton (*Sporobolus airoides*), sideoats grama (*Bouteloua curtipendula*), cane bluestem (*Bothriochloa barbinodis*), green sprangletop (*Leptochloa dubia*), chisos bluebonnet (*Lupinus havardii*), and showy menodora (*Menodora longiflora*). Because of their unique ability to grow on steep, rocky slopes, we also agreed to collect seed of false grama (*Cathestecum erectum*) and chino grama (*Bouteloua breviseta*) but no promises were made of our ability to successfully germinate, establish and produce seed of these two.

Lynn Pace, Texas Parks and Wildlife Department employee, stationed at the Knox City PMC, and I returned to the park in October, 1989, and hand-collected seeds of the selected species. Since the summer of 1989 did not produce any general rains over the park, areas of seed production were few. There were no bluebonnets that year and showy menodora was not in seed production mode.

We collected enough sideoats grama, cane bluestem and chino grama seed to plant them and half of the alkali sacaton directly into increase fields at the PMC. These fields are furrow irrigated with rows 182 feet long, spaced 40 inches apart. There were 26 rows of sideoats, 10 rows of cane bluestem, and 2 rows each of chino grama and alkaki sacaton established successfully. We collected so little green sprangletop and false grama we felt we needed to start them in the greenhouse and establish production blocks vegetatively. These efforts successfully established 2 additional rows of alkali sacaton and one half row of green sprangletop. From 2 rows of chino grama and one half row of false grama planted vegetatively, only 12 plants of chino survived. The false grama was a total failure.

Alkali sacaton, sideoats grama, cane bluestem and green sprangletop all produced seed in the fall of 1990. The seed was harvested and is being cleaned for planting this May. It is expected enough will be available to increase the size of the production blocks to about 1 acre each of sideoats gramma, cane bluestem and alkali sacaton. The green sprangletop can be expanded to a little over one half acre.

Lynn Pace and Ray Cragar, assistant manager at Knox City PMC, returned to the park in November, 1990 and collected additional sideoats grama, green sprangletop and alkali sacaton. They were also able to get showy menodora. One additional forb not on the list was collected to find out if propagation techniques can be developed. If so, that plant, limoncillo (*Pectis angustifolia var. tenella*) will be produced also. Only one species, chisos bluebonnet, remains to be collected. It is an annual that germinates in the fall and makes seed in May or June. One more attempt will be made late this spring to find seed.

The agreement between BBNP and Knox City PMC specifies seed be delivered between fall 1991 and spring 1993. It loolks like we will be successful in meeting our obligations. If you visit the park after the fall of 1992, you will see the results on the shoulders of Ross Maxwell Scenic Drive.

Use of Native Plants for Roadside Revegetation

E. LeRoy Brady, Roadside Development Services Manager Arizona Department of Transportation, Highways Division, Phoenix, Arizona

The Arizona Department of Transportation Highways Division follows the policy of minimizing erosion and sediment damage to the highway and adjacent properties. The practices of erosion control during construction and maintenance bring the department into compliance with State and Federal laws and rules for erosion and sediment control. Just as important as compliance to the law is, the spirit with which erosion control by revegetation is carried out has a major effect. It is that spirit that convinces engineers and other highway design professionals of the environmental advantages and not to be ignored economic benefits of filling the ecological nitches created by construction and maintenance with native and appropriate introduced plants.

Roadside slopes are usually determined by engineering-geotechnical criteria established to minimize disturbance and material movement, right of way required and safety requirements. Consequently, we are usually working with steep slopes, soils of low fertility and even bio-toxic conditions. The limiting factors are compounded by low rainfall and limited rainfall effectiveness due to the slopes and compacted soils that are associated with highway construction.

We have learned to counteract these conditions by using amendments to improve the condition of the soil, plate toxic soil areas, flatten or bench slopes and rip and till compacted soils to enhance the potential for successful revegetation. Revegetation in desert areas — there is enough chance left to Mother Nature. Adequate implementation of preparation requirements is an absolute must for success.

Most highway projects provide an opportunity to determine what the soil problems will be or what toxic conditions must be dealt with during construction. In Arizona many of the soils are high in salts and frequently the offender is sodium. Environmentally sensitive areas and projects in urban areas are given special consideration. An example is a 110 acre traffic interchange area west of Phoenix which 3 years after construction was completely barren because of high salts, with sodium as high as 39%. The treatment was a combination of 8,000 pounds of gypsum and 400 pounds of sulphur per acre, tilled in and then plated with 6 inches of soil which was seeded, mulched and today supports native vegetation. This native vegetation controls erosion and visually blends the right of way with the surrounding area.

Selection of seed mixes must be related to the soil, rainfall patterns and seasonal characteristics which in Arizona are most closely tied to elevation.

A seed mixture that would be used in the Tucson and Phoenix Areas —

A low elevation seed moisture. Below 4500 ft.

Seed Species	Rate per Acre
Cochise lovegrass (*Eragrostis Trichopora*)	1#
Lehmann lovegrass (*Eragrostis lehmanniana*)	1#
Mediterraneangrass (*Schismus barbatus*)	2#
California poppy (*Eschscholtzia Californica*)	3#

A seed mixture that would be used in the Prescott and Payson areas —

A medium elevation seed mixture. 4500-6500 ft.

Seed Species	Rate per Acre
Blue grama (*Bouteloua gracilis HACHITA*)	1#
Crested Wheatgrass (*Agropyron desertorum Nordum*)	3#
Sideoats grama (*Bouteloua curtipendula Vaughn*)	3#
California poppy (*Eschscholtzia Californica*)	3#
Indian blanket (*Gaillardia puchella*)	1#
Streambanks wheatgrass (*Agropyron riparium Sodar*)	3#
Cicer milkvetch (*Astragalus cicer*)	2#

A seed mixture that would be used in the Flagstaff and Williams areas —

A high elevation seed mixture. 6500-7500 ft.

Seed Species	Rate per Acre
Pubescent wheatgrass (*Agropyron trichophorum Lune*)	3#
Western wheatgrass (*Agropyron smithii, Barton*)	3#
Sideoats grama (*Bouteloua curtipendula Vaughn*)	4#
Blue grama (*Bouteloua gracilis*)	1#
Blue flax (*Linum Lewisi*)	1#
Penstemon (*Penstemon eatonii*)	1#

A preference to seeding by drilling is given in all areas that are neither too rocky nor too steep. Straw mulch is used over these seeded areas at 2-1/2 tons to the acre where it can be crimped into the soil. In areas where the straw is not easily crimped it is held in place with a tacking agent. In these areas the rate is reduced to 1-3/4 tons per acre, to prevent excessive shading of the soil surface and to more effectively tack the straw in place. The tacking agent most often is an organize blinder at 150 pounds per acre in a slurry of 700 gallons of water and 400 pounds of wood fiber.

During the last 10 years the Department has seeded over 7,000 acres at a cost that has gradually increased to average over $1,000 per acre. Hydroseeding and mulching is used only in areas where other methods are not appropriate because of slope, location or soils.

Among the native plants that we have seeded are the following slides:

1. Cercidium floridum - Blue Palo Verde, the Arizona State Tree. Bailey MultiRada
2. Sporalsla Desert Globe mallow
3. Cassia covesii
4. Lupinus Arizonicus
5. Eschollzia Mexicana - Mexican poppy
6. Encelia farinosa - Brittlebush
7. Kallstromia grandiflora - Arizona poppy
8. Bladderwort
9. Sand verbena
10. California bluebells
11. Gullardia puchella - Indian blanket
12. Dysodia pentaflora
13. Zinnia acerosa
14. Penstemon

Seed availability is frequently limited or not available for many species. Some seed collectors are beginning to grow the various species which is helping to assure availability as well as lower the price.

Developing a Vegetation Management Program

Roy L. Smith, Texas State Department of Highways and Public Transportation, Austin, Texas

Simply stated, vegetation management is the growing and managing or maintaining vegetation to accomplish a particular goal. The objective defines or narrows the parameters in which you work to achieve or accomplish this goal with regard to vegetation management.

In Texas the highway system crosses ten different major vegetational areas and encompasses approximately 1,050,000 acres. The goal is to have a highway right-of-way that is compatible if possible with the adjacent property and blends with the vegetation zone through which it passes. The objectives are to preserve, select, establish, and maintain vegetation on the highway right-of-way which achieves the goal established.

This may seem a bit mechanical in its approach, but you must know what you want to achieve in order to develop a vegetation management program.

To achieve the desired vegetation there must be a committment to the objectives set forth and this should start prior to construction activities.

The first phase of a vegetation management program is to preserve the existing native vegetation. This may involve limiting areas to be disturbed during construction. This not only preserves valuable vegetation, but also reduces the areas which need to be revegetated.

Secondly, there should be a knowledge or understanding of the vegetational area to properly select grasses, wildflowers, and landscape plants to be used in restoring the disturbed areas. These plants should be selected with regard to their ability to revegetate or establish, maintenance requirements, and aesthetics desired. Also availability of seeds and plants is an important consideration.

Thirdly, proper planting techniques must be explored and refined or even developed to insure establishment. The best planting time must be determined to achieve survival. Proper planting rates and mixtures must also be determined to achieve the desirable cover. In landscape plantings the quantity of plant material and spacing of plants must be determined to achieve the desired impact or design statement.

Fourthly, proper maintenance is essential to achieve the desired results. Maintenance has been mentioned in the selection of plant material and once planted this maintenance activity must be carried out to promote establishment. This maintenance may be watering, fertilizing, selective weeding, and mowing. Many times reseeding or replanting may be necessary to maintain or achieve the desired results. It is during this fourth stage when the word management normally plays a part. As the right-of-way develops proper management tools will need to be used. With respect to function of a highway system, these management practices should promote a safe and pleasing experience for the travelling public as well as protect the investment.

The aforementioned criteria are implemented in Texas in the following ways. Grass seeding specifications have been written to involve the native grasses for each of the ten vegetational zones. Planting techniques have been researched and continue to be updated. Wildflowers for each area of the State have been identified as to their adaptability and availability.

Landscape plantings use as many native plants as possible, depending on availability and design requirements. Ornamentals are used when and where they are needed to achieve the design concept. Temporary irrigation is also designed and included in the contract plans to increase establishment. Supplemental maintenance contracts are also used to reduce the impact on already burdened maintenance forces.

Mowing standards have been developed to give guidelines for safety mowing, wildflower preservation, cutting heights, and designated non-mow areas. Along with mowing standards there is a herbicide program designed primarily as a pest plant management tool. Herbicides are used to control vegetation along the edge of pavement and around highway fixtures (signs, delineators, guardrails). The herbicide program is designed to mesh with a limited mowing program and not to replace it. An example being to reduce the infestation of johnsongrass, thereby encouraging more desirable vegetation and reducing the need or frequency of safety mowing.

The emphasis in Texas is on a right-of-way which has a community of plants which blends with and enhances the environment. A weed is not a weed if it blooms in Texas; it is a wildflower.

Yellowstone National Park-Bridger Plant Materials Center Native Plant Program

Mark E. Majerus, Agronomist, USDA Soil Conservation Service, Plant Materials Center, Bridger, Montana

With the passage of the National Surface Transportation Assistance Act of 1982, Congress recognized a nationwide need for rehabilitating and upgrading deteriorating road systems in national parks. With Federal Highway Commission money, Yellowstone National Park initiated reclamation and landscape plans for the Craig Pass road project, a 30-kilometer stretch from Old Faithful to West Thumb. In the past, revegetation within Park boundaries was accomplished by natural means, i.e., plant propagules originating from salvaged topsoil or dispersing from adjacent, undisturbed plant communities. In 1986, through a cooperative agreement between the National Park Service (NPS) and the USDA-SCS Plant Materials Center (PMC) at Bridger, Montana, collections of seed were made of native, indigenous grasses, forbs, and shrubs. Seed collections were taken to the Bridger PMC, cleaned, and planted in seed production fields or propagation beds. Produced seed and plants are returned to the park for revegetation of disturbed roadsides.

The reasoning behind this revegetation approach is to be able to seed large areas with native, indigenous plant material and produce a plant cover faster than would be realized with natural succession. A quick plant cover will protect road cuts and fills from surface wind and water erosion, and will hopefully compete with invading weedy species. The decision to take this approach in road construction revegetation has created many unanswered questions and much controversy concerning the protection and preservation of the indigenous gene pool. Some of the questions, for example, are:

1. Because the roadway creates an artifically exposed site within a forest community, what species can be considered indigeous to this site?
2. What constitutes the limits of a genotype; how far away can you collect and still be within these limits?
3. What species can be collected and produced using cultivation techniques?
4. By taking seed outside the park to a dissimilar climate to produce seed, is genetic drift or natural selection going to affect the genetic integrity of this plant material?, and
5. Is the planting of this collected and produced material going to significantly affect the development of plant material from the naturally occurring seed sources?

Through the activities of the Bridger PMC, an attempt is being made to answer some of these questions.

Seed Collection

When a roadway is constructed through a forest plant community, the native species for these exposed road cuts are no longer the forest and understory species, but rather those species that would invade and colonize on these exposed sites. By examining abandoned roads, old disturbances, and open park and meadows within the predominantly lodgepole pine forest types, it was possible to get an idea of the species that should be utilized. All seed collections were within Park boundaries and within 8-10 kilometers (km) of the reclamation sites for which they were to be used. The genetic variability within and among plant population varies by species based on geographic range, reproductive mode, mating system, seed disposal mechanism, and stage of succession (Hamrick 1983). Whether a species is self-pollinating or outcrossing also makes a difference in genetic variability. The selfing mode of reproduction limits the movement of alleles from one population to another and consequently increases genetic differences among populations. Plant species with wide ranges, long generation time, wind pollination, outcrossing mating systems, and that occur in the later stages of succession tend to have low variability within population and high variability among populations. Pioneer (early, successional) species also have less genetic variation within populations. The NPS is proposing a collection restriction of 5 km on short-lived, selfing species; 8 km on short-lived, outcrossing species; and 16 km on long-lived, outcrossing species. Currently, the interpretation of what constitutes a gene pool and the limits of a plant population does vary among the different national parks.

Seed collection within YNP utilizes a variety of seasonal laborers and volunteers under the supervision of the landscape architects and PMC plant specialists. Although various vacuum harvesters had been tried, most of the collection is done by hand stripping or using hand scythes. Harvested material is air dried and then transported to the Bridger PMC for cleaning. Since 1985, 360 seed collections of 119 species have been made from 100 separate sites in YMP. Table 1 lists the major species collected and the rate of seed harvest. The speed at which seed can be collected depends on the stand densitry, degree of seed set, and the persons collecting. This table gives an idea of the time and expense of hand harvesting native plant materials.

Table 1. – ***The major species collected in Yellowstone National Park and the rate at which the seed can be hand collected.***

Genus & Species	Average Collection Rate *(g/manhr)*	Range
Leymus glaucus	512	75-2552
Elymus trachycaulus	454	136-976
Poa species	349	54-580
Bromus marginatus	294	33-1008
Agrostis species	95	29-140
Deschampsia cespitosa	87	38-141
Festuca idahoensis	85	56-162
Elymus elymoides	78	16-195
Stipa occidentalis & richardsonii	49	18-66
Stipa comata	36	21-68
Genus & Species	**Average Collection Rate *(g/manhr)***	**Range**
Achillea millefolium	162	125-188
Penstemon species	156	20-454
Chaenactis douglasii	148	21-267
Helianthella uniflora	130	69-214
Eriogonum umbellatum	121	37-263
Phacelia hastata	69	4-300
Lupinus species	61	9-222
Aster integrifolius	55	3-136
Anaphalis margaritacea	55	3-149
Solidago species	50	25-65
Potentilla species	40	12-110

Seed and Plant Production

The Bridger PMC is located approximately 160 km northeast of YNP on 55 hectares of irrigated land. The elevation is 1,128 meters, and the average growing season is 130 days. Seed is being collected from sites at 1,800 to 2,400 meters that have less than a 100-day growing season. Seed of alpine plants (3,000 m elevation) have been successfully produced in the past at the PMC. The biggest short-coming of this site for producing seed of mountainous species has been the hot, dry spring weather. However, seed of the short-lived, self-pollinating species such as mountain brome *Bromus marginatus*, slender wheatgrass *Elymus trachycaulus*, blue wildrye *Leymus glaucus*, and bottlebrush squirrel tail *Elymus elymoides* are relatively easy to raise.

Seed production fields are established by seeding 1-m spaced rows at a rate of 90 pure live seeds per linear meter of row. Fields are flood irrigated, fertilized (60 kg nitrogen/hectare, 40 kg phosphorus/hectare) and cultivated following standard procedures used by most commercial seed rowers. Extensive hand roguing is used to minimize contamination with weeds or off-types. Depending on the species and the size of the field, seed is harvested by hand or with a small combine. A Woodward Flail-Vac has been purchased to harvest the more difficult species, i.e., those with long awns or those that readily shatter.

In an attempt to determine if there is any genetic drift or natural selection when seed is produced at a site remote from the national park, Glacier National Park is funding a study at the University of Montana. Seed of three generations of mountain brome (original collection and two subsequent generations grown at the Bridger PMC) have been submitted for electrophoretical analysis and phenological comparison. Merrell (1981) stated that individuals developing at the same time, but under different environmental regimes, may have different phenotypes develop, even though their genotypes are essentially the same.

Forbs and shrubs for transplanting have been produced from seed and cuttings in the greenhouse in 164-cm^3 conetainers[1] or grown in outdoor propagation beds. Species successfully grown are listed in table 2.

Table 2. – ***Species grown in cone-tainers in a greenhouse or in propagation beds for transplanting back into YNP on disturbed sites.***

Conetainers/Greenhouse	
Helianthella uniflora	heterotheca villosa
Eriogonum umbellatum	Phacelia hastata
Anaphalis margaritacea	Potentilla species
Geranium viscosissimum	Antennaria species
Geranium richardsonii	Aster integrifolius
Achillea millefolium	Arenaria congesta
Penstemon cyaneus	Arnica species
Chaenactis douglasii	
Propagation Beds	
Berberis repens	Ribes idaeus
Prunus virginiana	Ribes species
Rhus trilobata	Acer glabrum
Cornus stolonifera	Rosa species
Symphoricarpos species	

Seeding Trials

Construction on the first 15 km section (Kepler Cascades to DeLacey Creek) was completed in the fall of 1988. At this time all cut and fill slopes were seeded with native indigenous plant materials that were either collected and grown at the bridger PMC or collected for direct reseeding. Because this was the first planting of this kind within YNP, plots were set up to monitor plant establishment and longevity along this road project.

Methods and Procedures

Seed Mixture Trials

In October of 1988, plots were set up on two topsoiled slopes, a south-facing slope (near Kepler Cascades) and a north-facing slope (near Scaup Lake). Replicated plots (22.5 square meters) were established in a split-split block design with mulch treatments (mulch-no mulch) as the main plot. Bark mulch (one-third cedar and two-thirds fir) was applied to a 2.5 cm thickness. The fertilizer treatments (fertilizer-no fertilizer) were arranged as subplot treatments. Fertilizer was applied at a rate of 10 kg nitrogen/metric ton of bark mulch. The seed treatments (seed-no seed) was arranged as sub-subplots. The seeded plots were hand broadcast with a mixture of native, indigenous grasses and forbs (table 3), while the unseeded plots relied on a seed bank in the replaced topsoil and seed dispersal from adjacent, undisturbed plant communities.

Table 3. – ***Species and amounts seeded in test plots at Kepler Cascades and Scaup Lake in Yellowstone National Park on October 14, 1988.***

Genus & Species	Seeds /Gram	Seeds Used *(gram)*	Seeds /$Meter^2$
Elyumus trachycaulus	335	232	123
Agrostis scabra	6,060	40	260
Bromus marginatus	150	386	96
Leymus glaucus	280	160	73
Phleum alpinum	1,575	73	136
Elymus elymoides	270	150	69
Lupinus argentea	65	36	0.3
Potentilla gracilis	3,330	80	358

Ten, random, 20- X 40-cm frames in each plot are being sampled three times during the growing season at approximately 5-week intervals so as to document plant mortality and plant composition changes.

Forb Trials

In the spring of 1989, on the first 15-km section of road, several greenhouse-grown, containerized forbs were transplanted along the roadway. This was a very labor intensive and impractical method of establishing forbs. If some of the pioneer-type forb species could be established from seed, the reclamation process would be simplified and more expedient. On the second 15-km section of road, replicated plots were established in October 1989 to compare germination, establishment, and longevity of twelve forb species (table 4).

Table 4. – ***Species included in the Forb Trials[1] (1.5 m X 4.5 m plots, 3 reps CRB) on a south-facing cut near Little Thumb Creek, along the Craig Pass road project in Yellowstone National Park. Planting was established September 28, 1989.***

Genus & Species	Seeds/gram	Seeding Rate (grams/plot)
Achillea millefolium	5,950	2
Antennaria umbrinella	13,200	1
Anapalis margaritacea	18,100	2
Arnica latifolia	900	3
Aster species	440	5
Chaenactis douglasii	680	5
Chrysopsis villosa	595	5
Eriogonum umbellatum	460	8
Lupinus species	65	25
Phacelia hastata	340	15
Penstemon cyaneus	395	8
Solidago species	1,540	4

[1]All plots were overseeded with a mixture of Elymus trachycaulus (68 g) and Bromus marginatus (147 g), equivalent to 70 seeds/m² of each species.

Five, random, 20-X40-cm frames in each plot were also evaluated three times during the growing season to monitor seedling survival and mortality.

Results

Seed Mixture Trials

The fertilizer that was applied to the fertilized plots (10 kg/metric ton of bark mulch) was the recommended amount to compensate for the nutrients required for the microbial decomposition of the mulch. During the first two growing seasons, there were no significant differences in plant density or composition among the fertilized and non-fertilized plots on either the south-facing (Kepler) or north-facing (Scaup) plots. (See figures 1, 2, and 3). There is apparently no need to apply fertilizer, at least at this low rate.

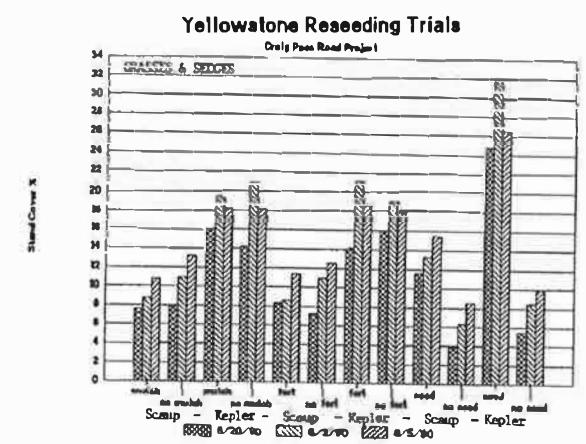

Figure 1. – *Percent cover of grasses and sedges in plots at Scaup Lake and Kepler Cascades. A comparison of three treatments at three dates during the 1990 growing season.*

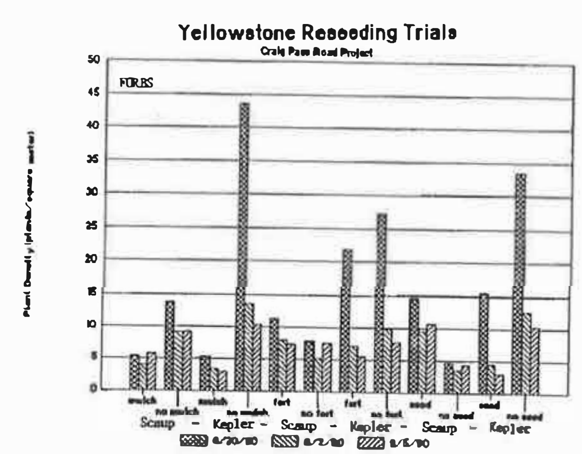

Figure 2. – *Plant density of forbs (both seeded and invading) in plots at Scaup Lake and Kepler Cascades. A comparison of three treatments at three dates during the 1990 growing season.*

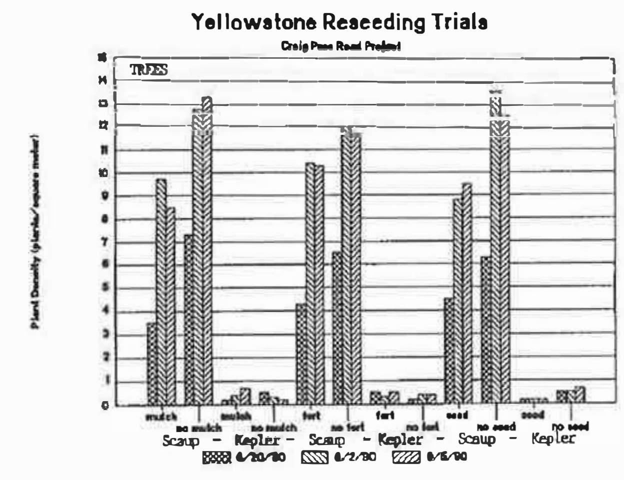

Figure 3. – *Plant density of lodgepole pine in plots at Scaup Lake and Kepler Cascades. A comparison of three treatments at three dates during the 1990 growing season.*

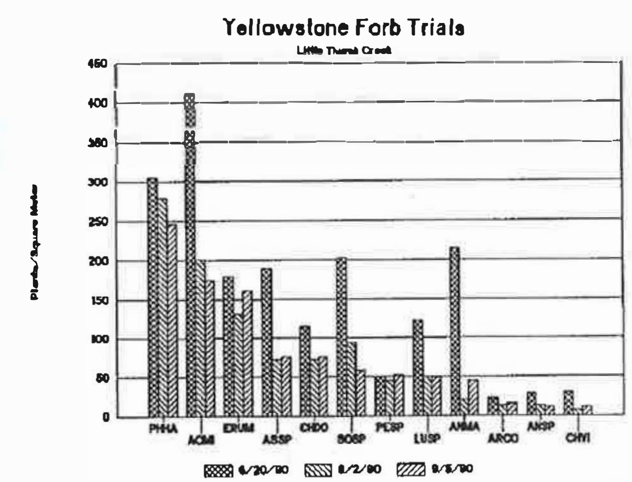

Figure 4. – *Plant density of forb seedlings in replicated plots near Little Thumb Creek at three dates during the 1990 growing season.*

The bark mulch treatment was applied to the cut and fill slopes along the entire road project to protect against surface erosion and to help retain surface moisture for better seedling establishment. When the contractor applied mulch to the plots, portions of the Scaup Lake plots were covered with 5-10 cm of mulch. The excessive mulch resulted in slower establishment and a significantly lower stand density the first year. However, during the second year there were no significant differences among the mulched and unmulched plots at either site. On the unmulched, unseeded plots at Kepler Cascades (south-facing slope), an annual forb, groundsmoke Gayophytum diffusum, established a dense stand, while on the mulched, unseeded plots there were only a few scattered plants. Mulching had considerably restricted this plant's establishment. Although mulching did not help develop better plant stands on the first section of road (1988 seeding), the late mulching (June rather than previous October) may have been a contributing factor to the relatively poor stands on some of the slopes on the second section (1989 seeding).

Significantly better plant cover was established by seeding with a mixture of native, indigenous species than by relying on the seed bank in the salvatged topsoil. An analysis of topsoil samples, prior to planting, indicated that only seed of sedges Carex species, lodgepole pine Pinus contorta, lupine Lupinus species, and pussypaws Spraguea umbellata were present. In the unseeded plots at Kepler Cascades and Scaup Lake, these were the only species to establish the first year.

Germination was later and plant development was slower at the Scaup Lake plots than at the Kepler Cascade plots because of the cooler soils and less exposure on the north-facing slope. After two growing seasons, all the seeded grasses at Kepler Cascades were headed out and produced viable seed; while at Scaup Lake the plants had a much shorter stature, and only a few of the grasses headed out. Also at Kepler Cascades, most of the forb and tree seedlings perished by the end of the first growing season, while at Scaup Lake most have survived two growing seasons. Thus far the best seeded grasses have been mountain brome, rough bentgrass, and slender wheatgrass (table 5). The sedges—Ross sedge *Carex rossii* and elk sedge *Carex geyeri*—are dominating the unseeded plots. There are similar numbers of sedge plants established in the seeded plots, but because of competition from the seeded grasses, the individual sedge plants are smaller. The seeding of these slopes has not restricted the establishment of those plants originating from the natural seed bank. The plant communities that will persist on these slopes will be a combination of plants originating from the natural seed bank and the seeded material—all of which are indigenous to disturbed sites in close proximity of this road project.

Table 5. – *Average plant composition of seeded and unseeded species over all seeded plots at the two test sites along the Craig Pass Road Project in Yellowstone National Park. Estimates made on 9/14/89 and 9/5/90.*

Genus & Species	Scaup Lake % Composition 1989	Scaup Lake % Composition 1990	Kepler Cascades % Composition 1989	Kepler Cascades % Composition 1990
SEEDED: Bromus marginatus	19	26	21	34
Elymus trachycaulus	14	18	15	24
Argrostis scabra	18	20	30	15
Elymus elymoides	5	10	8	7
Leymus glaucus	10	1	5	2
Phleum alpinum	9	1	7	4
Lupinus species	3	2	2	1
Potentilla gracilis	7	5	4	1
NONSEEDED: Carex species			8	10
Pinus contorta	13	15	1	Trace
Epilobium angustifolium	——	——	Trace	Trace
Spraguea umbellata	Trace	Trace	Trace	Trace
Gayophytum diffusum	——	——	Trace	2

Forb Trials

The south-facing slope used for the replicated forb plots was not mulched so as to provide a more severe environment on which to screen forbs for potential reclamation use. Yarrow (*Achillea millefolium*) had the highest plant density (400 plants/m^2) in early summer, but more than half of these seedings died by September (figure 4). Those yarrow plants that did survive are very strong, healthy plants. Silverleaf *phacelia Phacelia hastata* had the best seedling density at the end of the growing season. Sulfur buckwheat *Eriogonum umbellatum* not only had one of the lowest mortality rates during the summer, but it also had the highest rate of late germinating seeds. Most of these forbs can be easily collected, cleaned, and seeded. Yarrow is the easiest species to grow for seed production on a large scale. Because of poor seed set and often sparse native stands, both Arnica and Antennaria are difficult to collect and are not easily produced under cultiuvated conditions.

Literature Cited

Hamrick, James L. 1983. The distribution of genetic variation within and among natural plant populations. p. 335-348. In C. M. Schoenewald-Cox, S. M. Chambers, B. MacBryde, and L. Thomas (eds.), *Genetics and conservation, a reference for managing wild animal and plant populations.* Benjamin/Cummings Publ. Co., Inc., Menlo Park.

Merrell, David. 1981. Ecological genetics. University of Minnesota, Minneapolis.

Innovative Devices for Rangeland Seeding

H. T. Wiedemann, Professor, and B., T. Cross, Research Associate, Texas Agricultural Experiment Station, Vernon, Texas

Abstract

Since 1970, the Texas Agricultural Experiment Station has conducted a program to develop range seeding equipment which has produced several notable advancements. The most significant was a seed metering device of our design which reduced the variation in seeding rates of chaffy grass and it became the industry standard for grass drills. Six manufacturers of the device market over 85% of the grass drills. An advancement in aerial seeding was the adaptation of a positive dispensing system controlled by a microprocessor and radar to uniformly meter slick seed by compensating for variation in ground speed. A novel development for seedbed preparation was a disk chain designed to disk extensive acreages of debris-littered rangeland at pulling costs less than $15.00/ha ($7.00/ac). In cooperation with an Australian inventor, our current research is concentrating on a chain diker which incorporates a rotating anchor chain modified to produce a broadcast pattern of small basins 10-cm (4-in) deep. When the diker is pulled behind a disk chain, the combination provides tillage, land smoothing and basin formation and has increased seeded grass densities three fold compared to non-diked treatments.

Problem

Revegetation of rangeland with desirable forage plants could substantially improve livestock production and wildlife habitat. However, the practice has been hampered by the lack of properly designed equipment and the high cost of land preparation and seeding. Modified cropland equipment usually requires extensive and costly land cleanup before it can be used, and still, it may be plagued with problems. Seeding regimes often are orchestrated for a very high level of success when less costly techniques would give adequate results. Novel approaches are needed to encourage range revegetation.

Research was initiated by the Texas Agricultural Experiment Station (TAES) in 1970 to develop innovative equipment and more reliable techniques for rangeland rehabilitation. Early studies by Wiedemann and Brock (1975) found that land rootplowed for brush control is often too littered with brush debris to revegetate with conventional equipment. This paper describes a one-on-one poster presentation concerning several innovative technologies developed by TAES over the past 20 years on rangeland seedbed preparation and seeding that requires a minimum of land cleanup.

Surface Seeding Innovations

New Technology: Semi-circular seedbox with auger agitator for chaffy seed metering.

Significance: The seed metering device reduced variability in seed dispensing and it has become the industry standard. Six manufacturers of the device represent over 85% of the market. Over $200 million of grass seed has been planted with the device, and drill sales have been estimated at $10 to $20 million to meet the CRP demand. A Texas based company is one of the leading manufacturers.

Supporting Statement

Uniform metering of chaffy seeded grasses from drills has been a serious problem for many years (Brock et al., 1970). Moreover, much of the seeding equipment has been designed for clean-tilled land and does not withstand the rigors of rough land. To overcome the metering problems, a semicircular seedbox was constructed and several styles of agitators and pickerwheels were evaluated using sideoats grama (*Bouteloua curtipendula*) seed. A combination of the semicircular seedbox, auger agitator and 12.7-mm-wide (0.5 -in) pickerwheel with eight teeth gave the best results. This experimental metering device resulted in a seeding rate decrease of only 15% while metering 75% of the seed from the seedbox at a pickerwheel speed of 10 rpm (Figure 1). This compares to a seeding rate decrease of 99% before 75% were metered from the seedbox of a standard Nesbit rangeland drill using a pickerwheel speed of 30 rpm. Initial seeding rates were comparable for both units. The experimental unit easily metered 97% of the seed from the seedbox during static test conditions (Wiedemann et al., 1979).

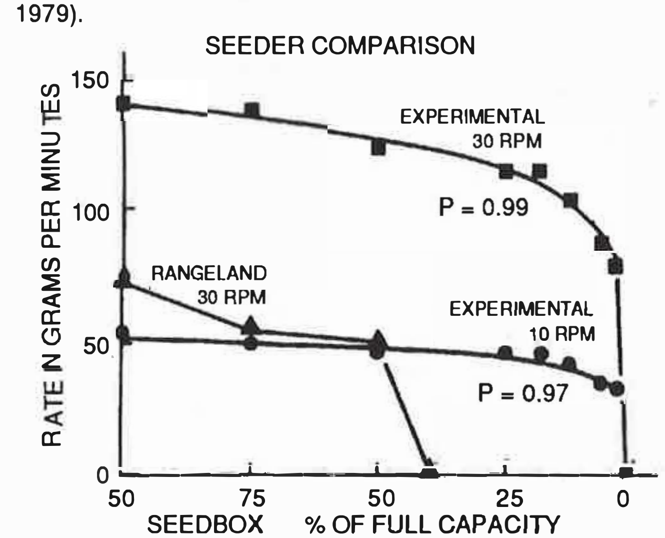

Figure 1. – Comparison of uniform seeding rates of the experimental chaffy seed metering device to the non-uniform rates of a standard rangeland metering device (Wiedemann et al., 1979).

Experiments also were conducted with caucasian bluestem (Bothriochloa caucasicus), little bluestem (*Schizachyrium scoparius*), buffelgrass (*cenchrus ciliaris*), galleta (*Hilaria jamesii*), fourwing saltbush (*Atriplex canescens*) and winterfat (*Ceratodes* lanata). The semicirular seedbox with auger agitation dispensed at least 97% of the seed of each species from the box. Seeding rate as a function of the amount of seed in the hopper was predicatable with significant r^2 values over 0.90 based on regression analysis. Buffelgrass seed, one of the most difficult to meter, had a decrease in seeding rate of only 33% while metering 75% of the seed from the seedbox. These experiments are described by Wiedemann (1982 and 1984).

A prototype seeder with the chaffy seedbox was mounted on a heavy-duty frame with flexing runner openers capable of traversing a 30-cm (12-in) log (Wiedemann and Cross, 1981) (Figure 2). Five years of field testing on debris-littered land is discussed by Wiedemann et al. (1979). Seedling densities in areas planted with the experimental seeder were 107% greater than similar areas seeded aerially.

Figure 2. – Prototype rangeland seeder with chaffy seed metering device and individual hoppers for slick seed, and flexing runner openers to place seed in he furrow without undue breakage from brush debris. Foam-filled tires prevent flats.

Both the seed metering and placement devices functioned well; however, acceptance of the technologies differed. The chaffy seed metering system became the industry standard. The flexing, runner openers have been used on a very limited basis because log-littered land is usually raked if a surface seeder is to be used. Raking allows drill seeders with double-disk openers to be utilized, and the lack of debris allows vehicle travel in the pasture.

Aerial Seeding Innovations

New Techology: Vaned rotor with microprocessor controls for positive metering of slick seed.

Significance: Aerial seeding is a viable option for rangeland, but conditions for success are more critical than those for drill seeding. Positive metering systems are accurate and they can be calibrated on the ground. Our average coefficient of variation was onlty 4% for 27 plots metering 1 to 3 bulk kg/ha (1 to 3 bulk lbs/ac). A radar speed sensor can be attached to compensate for ground speed variation. Freshly disturbed soil is critical for success. Disked seedbeds resulted in significantly better grass stands than seedbeds prepared with less soil disturbance. Soil crusted by rainfall reduced broadcast seeded stands by 80% compared to drill seedings; however, when soils were freshly disturbed there was little difference between the seedings. Aerial seeding has been widely used.

Supporting Statement

Aerial seeding offers a fast method for covering extensive areas of rangeland, but metering of grass seed from aircraft has posed numerous problems. Hard, slick seed flows evenly through the standard hopper gate opening only at high rates. When low seeding rates (0.5 to 2 kg/ha [0.5 to 2 lbs/ac]) of small slick seed are attempted, metering is erratic. A fluted baffle was developed that substantially improved dispensing (Wiedemann et al., 1980), but precision was not considered adequate.

Positive Metering Systems. Positive metering devices were researched by Bouse et al. (1982) and commercially developed by Elanco Products[1] 'Meterate' (Elanco) and Jack Duke 'Duke Metering System' (Duke). The vaned-rotor metering devices designed for pelleted products were adapted for grass seeding by Wiedemann (1985) (Figure 3). Without rotor modification, very small slick seed like lovegrass (*Eragrostis curvula*) or hulled bluestem (*Bothriochloa ischaemum*) must be mixed with a filler, such as ground milo on a 1- to-1 ratio by weight, to be metered accurately. Slightly larger seed, e.g. kleingrass (*Panicum coloratum*) or coated seed, meter well without rotor modification or filler. Field tests with the system resulted in an average coefficient of variation for 27 plots of 4.0% (Wiedemann and Cross, 1985a). During testing we determined that the metering system could be satisfactorily calibrated with the aircraft on the ground. Seeding rate could be adjusted by changing the rotor speed the same percentage that the actual seeding rate had deviated from the desired rate. Both the Elanco and Duke systems are available from Transland Aircraft, 24511 Frampton, Harbor City, CA 90710.

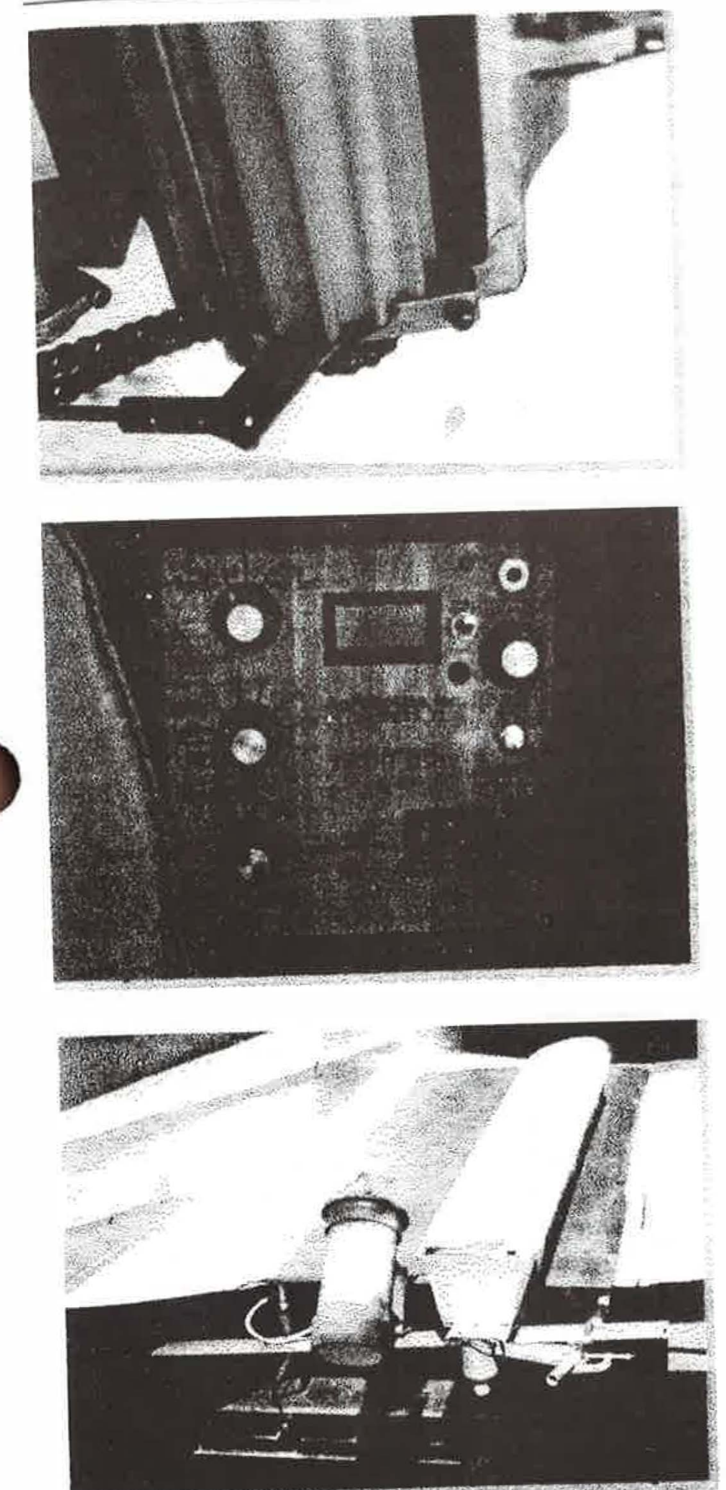

Figure 3. – Vaned rotor in positive meter system adapted for slick seed metering from aircraft (top view), computer device to control rotor speed (middle view), and radar speed sensor to measure true ground speed (bottom view).

Following these tests, Jerry Gebhiem, President, AgRobotics, Inc., Childress, TX developed a computerized speed control using a radar sensor to determine true ground speed for the aircraft's positive metering system. The desired seeding rate could be entered on the computer. A calibration check/adjustment was required while the plane was on the ground. In the air, the computer adjusted the rotor speed to compensate for variations in ground speed. Exploratory tests were very promising. AgRobotics terminated the project and Harold Hardcastle, President, Hardcastle Ag-Air, Inc., Vernon, TX 76384 purchased the development. No further commercial development has been conducted.

Chaffey Seed Metering. The positive metering system function well with small slick seed, but it cannot dispense chaffy seed. Sideoats and less chaffy seed normally can be metered through a hopper gate. Chaffier seed require some type of modification so they can pass through the hopper gate without bridging (Hardcastle, 1983). The chaffy seed can be coated and they meter well. However, the coating process is expensive and not readily available to producers. Another approach is to dehull the seed with a "shucker" attachment on the Woodward Chaffy Seed Conditioner developed by Aaron Beisel in cooperation with the USDA-ARS at Woodward, OK (Dewald et al., 1987). This system uses high speed air to strip the subtending appendages from the caryopsis (grain) with little damage to the seed. The small caryopses can be metered accurately from a positive metering system (Wiedemann and Cross, 1985a). Seeding with caryopses is an excellent approach if the seed can be planted without serious effects on germination and emergence.

Another alternative is to blend the chaffy seed with ground milo at a 1-to-2 ratio of seed to milo by weight plus another slick seed filler such as sorghum almum (*Sorghum almum*), kleingrass or millet (*Setaria italica*) at approximately 1 kg/ha (1 lb/ac)). Commercially, this adds about $1.00/bulk kg ($0.50/lb) of chaffy seed. All of our aerial chaffy seed metering research has been with WW Spar bluestem (*Bothriochloa ischaemum (L.) Keng var. ischaemum)*.

Timing of Aerial Application. During the 5-year equipment development phase, it was observed that timing of the aerial seeding in relation to rainfall was critical to seeding success. Results further indicated that disking prior to seeding improved grass stands significantly ($p < 0.05$) over other methods which disturbed the soil less (Wiedemann et al., 1979). Further studies conducted over a 3-year period showed that broadcast seeding (simulated aerial) on seedbeds crusted by rainfall reduced grass densities in excess of 80% compared to seeding on freshly prepared seedbeds (Cross, 1983). Therefore, there is a much higher probability that aerial seeding will be successful if it is conducted on a freshly disked seedbed and prior to the period when rainfall is most probable. Other considerations are covered by Dewald and Wiedemann (1985).

Disk Chaining Innovations

New Techology: Disk blades attached to alternate anchor chain links to provide disking action on log-littered land.

Significance: Disk chaining can reduce rangeland disking costs as much as 66%. The unit can traverse logs, stumps and small shrubs thus often eliminating the need for raking. Development of a single tractor pulling technique and a flexing roller has enhanced its acceptability. Grass densities on seedbeds prepared by disk chaining and offset disking were not different but both were significantly better than chaining. Disk chains are being used by the Bureau of Land Management (Green Stripping to contain wildfires) and Forest Service in seeding projects. Drawbar draft and depth of cut can both be predicted. A 104 kW (140 hp) crawler tractor can pull a 12.2 m (40-ft) wide, 20-blade unit at 4.8 km/h (3 mph) for a cost of $14.87/ha ($6.02/ac) ($65.00/h).

Supporting Statement

Early studies by Wiedemann et al. (1979) on rootplowed land showed that seedbeds prepared with a heavy-duty offset disk consistently produced better grass stands than roller chopping or chaining, but log-littered land often precluded the disk's use. A disk chain was developed that could traverse debris, reduce the cost of rangeland disking and eliminate the need for costly raking (Wiedemann and Cross, 1982) (Figure 4). A disk chain is an anchor chain with disk blades welded to alternate chain links. Disking action occurs when the chain, with swivels attached to each end, rotates as it is pulled diagonally.

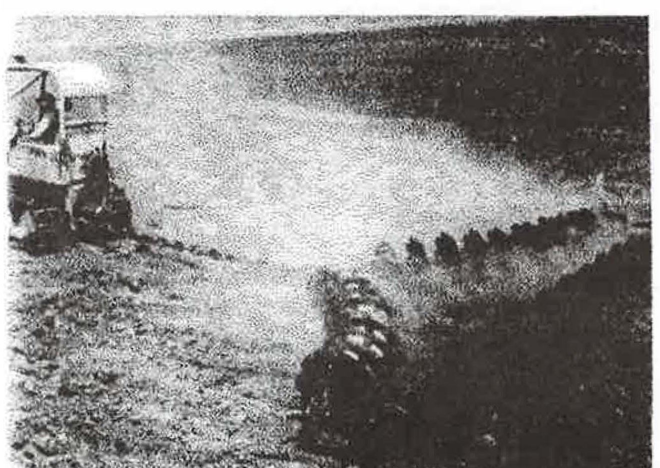

Figure 4. – Disk-chain developed for seedbed preparation on log-littered rangeland. Disking is achieved as anchor chain with blades welded to alternate links rotates.

Initially the disk chain was pulled diagonally between two tractors. Development of a triangular pulling method (Figure 4), which required only one tractor, decreased draft by 36% and increased the operating width by 23% over the two-tractor diagonal method (Wiedemann and Cross, 1985b). A draft measuring system for mobile equipment was developed for these studies (Wiedemann and Cross, 1983). Per-blade draft requirement of various combinations of disk blade and chain sizes within the range of 32 to 59 kg/blade (74 to 228 lbs/blade) is predicted by the relationship illustrated in Figure 5, addition of 1 kg (1 lb) of mass/blade increases draft by 18.3 N (1.9 lb of mass/blade icreases draft by 19.lbs) (Wiedemann and Cross, 1987). Disk blade cutting depth is also illustrated for various soil conditions.

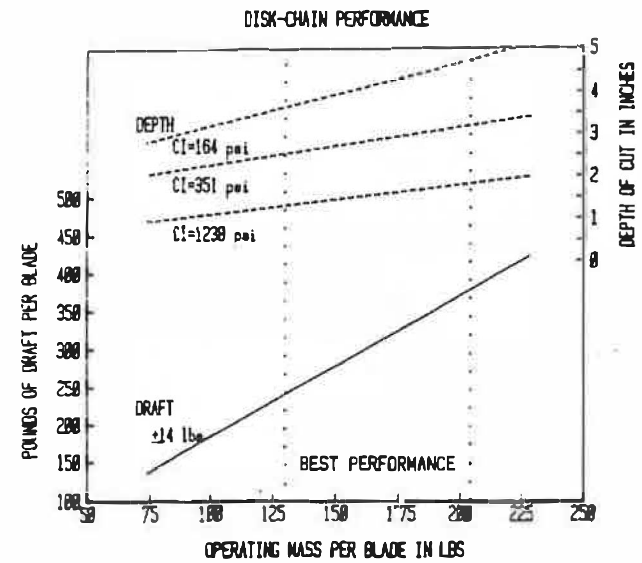

Figure 5. Draft and depth of cutting for various operating masses/ blade of disk chains pulled in different soil conditions delineated by ASAE cone index values (Wiedemann and Cross, 1987).

An extensive discussion of the many engineering indices influencing performance is covered by Wiedemann and Cross (1990), including the development of a flexing joint in the roller (Figure 5) to traverse logs and stumps. Their work showed that the 64-mm (2.5-in) diameter anchor chain and 711-mm (28-in) diameter disked blades gave the best performance over a broad range of test conditions. Moreover, the disk chain has traversed 40x180-cm (16x72-in) logs and 60x90-cm (24x36-in) stumps on rootplowed land.

In seeding studies over a 3-year period, grass densities were increased 35 and 92% over seedbeds prepared by non-modified (smooth) chains in loamy sand and clay loan, respectively. There were no significant differences in grass densities between seedbeds prepared by disk chaining (7.2 plts/m² [0.67 plts/ft²]) and offset disking (6.9 plts/m² [0.64 plts/ft²), but both were significantly higher ($p < 0.05$) than chaining alone (4.7 plts/m² [0.44 plts/ft²]) (Wiedemann, 1985).

The disk chain is being used by the Bureau of Land Management to install "green strips" to contain wildfires in the northwest United States (Pellant, 1989) and it has reduced costs in Forest Service seeding tests by two-thirds (Monsen, 1989).

Chain Diking Innovations

New Techology: Special shaped blades welded to anchor chain links to form basins for seedbed enhancement.

Significance: The chain diker forms about 45,000, 10-cm deep basins/ha (18,000, 4-in deep basins/ac). Pulling the chain diker behind the disk chain achieves tillage, land smoothing and basin formation in a single pass, and greatly improves the operation of the disk chain. The chain diker increases drawbar draft by 20% when it was pulled in combination with the disk chain. Grass densities were increased 3 fold in diked versus non-diked treatments when rainfall was 37% below normal;. Chain dikers are being used on flat-tilled cropland to reduce runoff. Diking increased wheat production by 11% compared to non-diked treatments when rainfall was below normal. When rainfall was 25% above normal, diking did not improve grass stands or wheat production compared to non-diking treatments; however, diking did reduce runoff by 21.2%. Agronomic units were designed to be pulled behind a disk, chisel or drill at 8 to 9 km/h (5 to 5.5 mph), and they required 2.2 drawbar kW/m (0.9 hp/ft) of width to be pulled at 8.1 km/h (5 mph). The novel diking technique appears promising.

Supporting Statement

The chain diker uses special shaped blades welded to opposing sides of each link of a large anchor chain. As it is pulled over tilled land, the chain rotates and the blades leave a broadcast pattern of diamond-shaped basins 10-cm (4-in) deep (Figure 6). Construction of the chain diker is in collaboration with its inventor, Bruce Smallacombe, Capella Sales and Engineering, Capella, Queensland 4702, Australia. When the chain diker is pulled behind the disk chain the combination tills, smoothes the land and forms basins all in one pass. The combination is called a "disk-chain-diker" (Figure 7). The chain diker can traverse any size brush debris the disk chain can travers.

Diking increased grass stand densities 3 fold compared to non-diked treatments (11.0 vs. 3.7 plts/m² [1.02 vs 0.34 plts/ft²]) on disk-chain seedbeds when May/June rainfall was 37% below normal. In year 2, when May/June rainfall was 25% above normal (235 mm [9.24 in]), there was no difference in grass stands, all were excellent (15.9 plts/m² [1.48 plts/ft²]). Diking appears to have the best potential to increase grass stands when rainfall is in short supply.

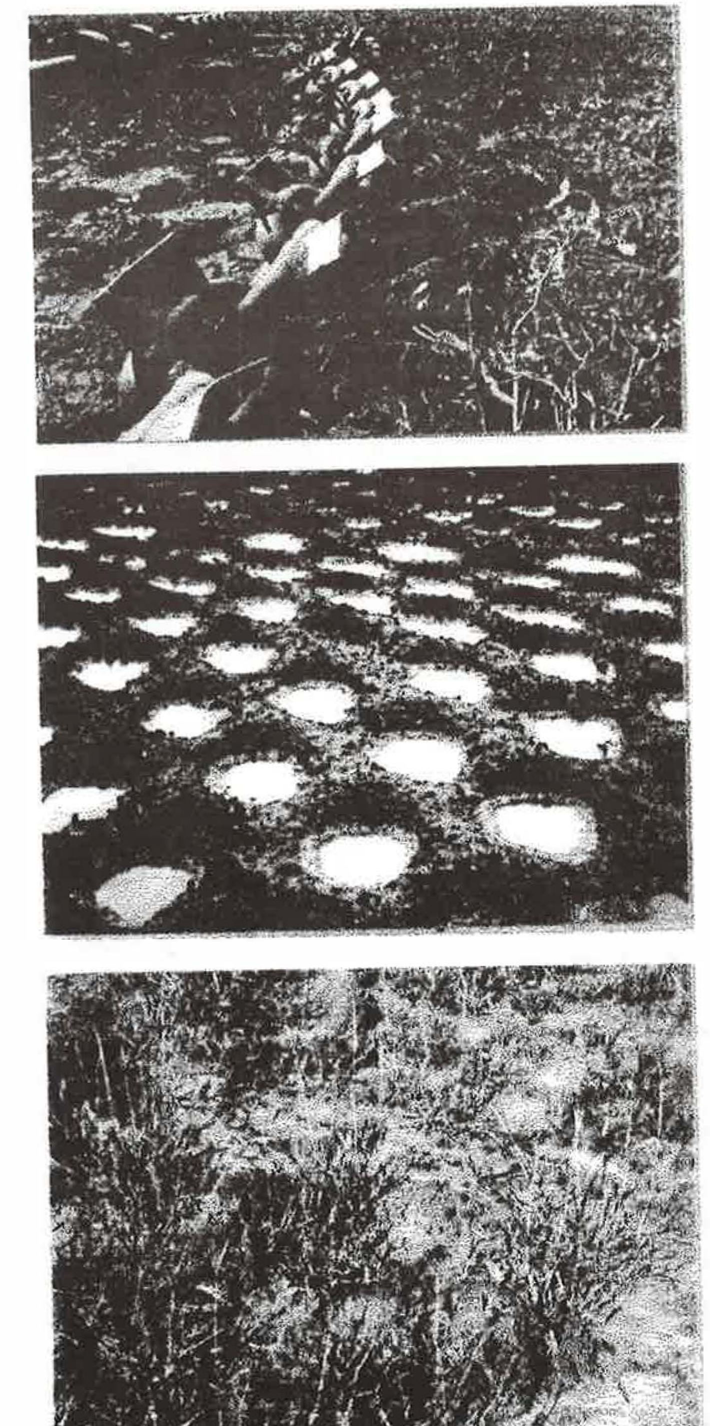

Figure 6. – Chain diker developed for enhanced seedbed preparation. Small basins are formed as chain rotates (top view). Small basins after rain (middle view) and grass plants in basins (bottom view). Technology is also useful to reduce runoff on flat-tilled cropland.

The basic disk-chain-diker is a 20-disk-blade unit using 64-mm (2.5-in) diameter anchor chain with 711 mm (28-in) diameter disk blades, a 500 mm (20-in) diameter flexing roller for a center brace (10.7-m (35-ft) wide), and a 76mm (3-in) diameter anchor chain with the special-shaped diking

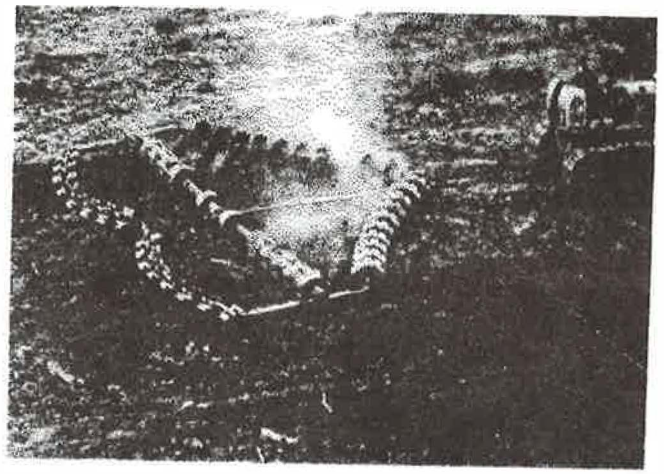

Figure 7. – The combined disk chain and chain diker implement provides tillage, land smoothing and basins formation all in one pass on log-littered rangeland.

blades (Figure 8). Average drawbar draft of this unit is 2.29 kN/blade 0.08 (515 lbs/blade 19) when pulled between 3.2 and 4.8 km/h (2 and 3 mph), the chain-diker unit accounted for 20% of the draft. The basic unit requires 3.03 kW (4.07 hp)/blade of drawbar power to operate at 4.4 km/h (3 mph) (Figure 8). The 20-blade unit is a full load for a 104 engine kW (140 hp) crawler tractor. At a contractor's rate of $65.00/hr for the crawler tractor, the pulling cost would be $18.45/ha ($7.47/ac).

Chain dikers show promise for reducing runoff on flat-tilled cropland. Agronomic units are designed to be pulled behind a disk, chisel or drill at 8 to 9 km/hr (5 to 5.5 mph) and cost about $1150/m ($350/ft). Required drawbar power for this style unit was 2.2 kW/m (0.9 hp/ft) of width at 8 km/hr (5 mph). Diking increased wheat production 11% ($p<0.05$, compared to conventional tillage the first year when rainfall was 16% below normal: however, ther was no difference in yield the second year when rainfall was 28% above normal (800 mm [31.5 in]). Runoff was reduced 21.2% ($p < 0.05$) by diking during crop season 2.

Further information on the chain diker and disk-chain-diker is covered by Wiedemann and Smallacombe (1989) and Wiedemann and Cross (1990), respectively.

Conclusions

The chaffy grass seed metering device significantly increased the stability of seeding rates for grass drills and became an industry standard.

Positive metering systems substantially reduced variability in aerial dispensing of grass seed. Since every lot of grass seed is slightly different and meters differently, the ability to

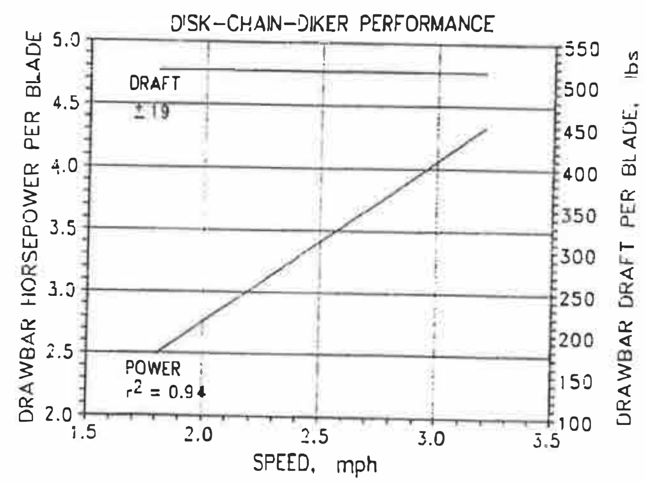

Figure 8. – Drawbar power and draft requirements of the basic disk-chain-diker for various speeds.

calibrate the airplane's metering system on the ground in a few minutes and then dispense load after load with little variation in seeding rate, is significant advancement. Seed modification allows the metering of chaffy grass seed, which previously was not possible.

The disk chain prepares an adequate seedbed for grass seeding on log-littered land, and it is cost effective.

Combining the chain diker and the disk chain has resulted in a novel method to till and smooth land and form basins all in one pass on log-littered land. Moreover, the basins enhance stand establishment when moisture is in short supply. The chain diker also shows promise for reducing runoff for flat-tilled crops.

These innovative devices offer effective techniques to rehabilitate rangelands worldwide.

References

Bouse, L.F., J.B. Carlton and J.C. Brusse. 1982. Dry metering system for aircraft. *Transactions of the ASAE* 25(2):316-320.

Brock, J.H., E.D. Robison, C.E. Fisher and C.H. Meadors. 1970. Re-establishment ofgrasses following mechanical removal of brush. PR-2810:43 in *Brush Research in Texas 1970.* Texas Agr. Exp. Sta. Consol. PR 2801-2828.

Cross, B.T. 1983. Seedbeds and seeding methods. P. 20 in H.T. Wiedemann and J.F. Cadenhead, eds., *Symposium Proc. Range and Pasture Seeding in the Southern Great Plains.* Texas A&M Univ. Agr. Res. & Ext. Ctr., Vernon, TX.

Dewald, C.L., V.A. Beisel and P.L. Sims. 1987. Concepts and principles of the Woodward chaffy seed conditioning system. *Symposium Proc. Seed and Seedbed Ecology of Rangeland Plants.* USDA-ARS. Tucson, AZ. P. 278-282.

Dewald, C.L. and H.T. Wiedemann. 1985. Improving rangeland seeding success. *Proc. of the 1985 International Ranchers Roundup.* Texas A&M Univ. Agr. Res. & Ext. Ctr., Uvalde, TX.

Duke, J. Duke Metering Equipment Company, Inc. Product literature. 559 Skyland Boulevard, Tuscaloosa, Alabama 34505.

Elanco Products Company, a division of Eli Lilly and Company. Product information. 740 South Alabama Street, Indianapolis, Indiana 46285.

Hardcastle, H.J. 1983. Experiences in commercial aerial seeding. Pages 44-45 in H.T. Wiedemann and J.F. Cadenhead, eds., *Symposium Proc. Range and Pasture Seeding in the Southern Great Plains.* Texas A&M Univ. Agr. Res. & Ext. Ctr., Vernon, TX.

Monsen, S. 1989. Personal communication. USDA-FS. Shrub Sciences Lab., Provo, UT 84601.

Pellant, M. 1989. Personal communication. USDI-BLM. Idaho State Office, Boise, ID 83706.

Wiedemann, H.T. 1982. Fluffy grass seed metering device for rangeland seeders. P. 178-182 in E.F. Aldon and W.R. Oaks, eds., *Symposium Proc. Reclamation of mined land in the Southwest.* Soil Conser. Soc. Of Amer. Albuquerque, NM.

Wiedemann, H.T. 1983. Fluffy seed metering systems for drills. P. 36-42. in H.T. Wiedemann and J.F. Cadenhead, eds., *Symposium Proc. Range and Pasture Seeding in the Southern Great Plains.* Texas A&M Univ., Agr. Res. & Ext. Ctr., Vernon, TX 76384.

Wiedemann, H.T. 1985. Advances in aerial grass seed metering. Paper No. 85-1504. ASAE, St. Joseph, MI 49085-9659.

Wiedemann, H.T. and J.H. Brock. 1975. Reseeding as affected by seedbed preparation, seeding methods and seeding rates following rootplowing. P. 38-40 in *Rangeland Resources Research 1971-74.* Texas Agr. Exp. Sta. Consol. PR3341.

Wiedemann, H.T., J.H. Brock, C.E. Fisher and B.T. Cross. 1979. Seed metering and placement devices for rangeland seeder. *Transactions of the ASAE* 22(5):972-977.

Wiedemann, H.T., C.H. Meadors, and B.T. Cross. 1980. Hopper-gate baffle for improved aerial metering of pelleted herbicides and seed. Pages 98-99 in *Rangeland Resource Research.* Texas Agr. Exp. Sta. Consol. PR 3665.

Wiedemann, H.T. and B.T. Cross. 1981. Rangeland seeder development using semicircular seedbox and auger agitator seed metering concept. *J. of Range Manage.* 34(4):340-342.

Wiedemann, H.T. and B.T. Cross. 1982. Draft of disk-chains for rangeland seedbed preparation. *Transactions of the ASAE* 25(1):74-76, 80.

Wiedemann, H.T. and B.T. Cross. 1983. Microprocessor with memory chip to collect transducer data on mobile equipment. *Agricultural Engineering* 64(11):7-8,11.

Wiedemann, H.T. and B.T. Cross. 1985a. Engineering systems for rehabilitation of arid lands. *Proc. Arid Lands: Today and Tomorrow.* Univ. of Arizona. p.871-881.

Wiedemann, H.T. and B.T. Cross. 1985b. Influence of pulling configuration on draft of disk-chains. *Transactions of the ASAE* 28(1):79-82.

Wiedemann, H.T. and B.T. Cross. 1987. Influence of operating mass on disk-chain performance. *Transactions of the ASAE* 30(6):1637-1640.

Wiedemann, H.T. and B.T. Cross. 1990. Disk-chain-diker selection and construction. Center Technical Report TR-1. Texas A&M University Research & Extension Center., Chillicothe-Vernon, Vernon, Texas 76384 (submitted).

Wiedemann, H.T. and B.A. Smallacombe. 1989. Chain-diker—a new tool to reduce runoff. Agricultural Engineering 70(5):12-15.