PROCEEDINGS:

HIGH ALTITUDE REVEGETATION WORKSHOP NO. 2

Edited by

R. H. Zuck and L. F. Brown

August 1976

COLORADO WATER RESOURCES RESEARCH INSTITUTE

Colorado State University
Fort Collins, Colorado

Information Series No. 21

HIGH-ALTITUDE REVEGETATION WORKSHOP NO. 2

Proceedings of a Workshop at Colorado State University

April 5-6, 1976

Edited by

R. H. Zuck[1] and L. F. Brown[2]

Colorado State University

In cooperation with:

Climax Molybdenum Company (AMAX, Inc)
Colorado Department of Highways
Colorado State Forest Service
Colorado Department of Natural Resources
Colorado Mountain College
University of Colorado
United States Forest Service (USDA)
Soil Conservation Service (USDA)
National Park Service (USDI)
Applewood Seed Company
Arkansas Valley Seed Company
Mile High Seed Company
Aspen Skiing Corporation
Breckenridge Ski Corporation
Vail Associates
Winter Park Recreational Association

J. A. Brown - Program Coordinator

[1]Range Science Department
Colorado State University
Fort Collins, Colorado 80523

[2]Environmental Control Engineer
Urad-Henderson Mines
Climax Molybdenum Company
Empire, Colorado 80438

Copies available through:
Environmental Resources Center
Colorado State University
Fort Collins, Colorado 80523

July 1976

PREFACE

Revegetation of disturbances at all elevations has become a major concern over the past 10 years. Development of techniques for revegetation of disturbances at high elevations has lagged behind techniques developed for lower elevations. The main reasons for this lag are the unique ecological problems encountered when attempting revegetation at high elevations. Some of the problems are:

1. The short growing season, with frost generally occurring every month of the year;

2. the extreme slope of most cuts and fills in mountainous terrain;

3. the common occurrence of 3 or 4 weeks of drought during the short growing season;

4. the scarcity of quality topsoil which, in many instances, mandates the construction of topsoil;

5. the sterility and coarseness of the subsoils which compound water relations problems;

6. the high light intensity and its affect on some vegetation;

7. the lack of commercially available seed of species native to high altitudes;

8. the low availability of nursery grown high-altitude shrub and tree ecotypes;

9. the erodibility of some soils;

10. the severe freeze drying effect of winter winds along with the scouring effects of blowing ice crystals;

11. the periodic presence of toxicities and acid seeps;

12. and, the oxidation potential of some of the materials which must serve as growth media.

These problems, most of which are unique to high altitudes, exemplify the difficulties encountered in revegetation of many sites.

These types of problems prompted the organization of a series of workshops and field trips to explore solutions, and to disseminate knowledge leading to solutions, for each unique high-altitude site. The first workshop was held January 31 and February 1, 1974 on the Colorado State University Campus. The proceedings were published as CSU Environmental Resources Center Information Series No. 10 (and are still available on request for $3.00). The first field trip was held the following August at the Climax Molybdenum Mine near Leadville, Colorado, and the Vail Ski Area, Vail, Colorado. The second field trip, held during the summer of 1975, inspected revegetation at the Urad Mine (Climax Molybdenum Co.), Winter Park Ski Area and a natural gas pipeline on the tundra of Corona Pass.

Organization of the first workshop was a direct result of cooperation between three people: Jim Brown (Climax Molybdenum Co.) and Bill Berg and Robin Cuany (CSU Agronomy Department). An outgrowth of the first workshop was the formation of what is presently referred to as "The Committee for High-Altitude Revegetation." This Committee was formed to obtain funding and initiate research on adaptation, breeding and seed production to enhance the quality, quantity and variety of seed needed for high-altitude revegetation. The research began in 1974 under the direction of Robin Cuany, and is funded by companies and agencies represented by various members of the committee.

This workshop (Workshop No. 2) was organized by some committee members in response to an ever growing need for solutions to high-altitude revegetation problems. Approximately 230 people took part in this workshop. The list of participants found in the last section includes only those who paid the registration fee, or who were speakers, etc. Many people dropped in for a short time and did not pay the fee.

Many participants expressed a desire for more such workshops and field trips. A field trip is planned for this summer, and we have begun thinking about Workshop No. 3, tentatively planned for March 1977.

On behalf of the committee and participants, I would like to express my appreciation to the speakers who presented the papers that follow.

Larry F. Brown

CONTENTS (PROGRAM)

WORKSHOP ON HIGH-ALTITUDE REVEGETATION

Committee for High-Altitude Revegetation (Jan. 1976)

Name and Affiliation	Address	Phone (office)
James Anderson Mile-High Seeds Co.	Box 1988 Grand Junction, CO 81501	242-3122
Dr. Robin L. Cuany (Comm. Chairman) Dept. of Agronomy, C.S.U.	Ft. Collins, CO 80523	491-6832 491-6517
Dave Bonnickson Mountain Manager, Peak Nine Breckenridge Ski Corporation	Breckenridge, CO 80424	453-2368
James A. Brown Environmental Control Engineer Climax Mine Climax Molybdenum Co.	Climax, CO 80429	486-2150 (closes 3:30 PM)
Dr. Larry F. Brown (Comm. Vice Chairman) Environmental Control Engineer Urad-Henderson Mines Climax Molybdenum Co.	Box 68 Empire, CO 80438	569-3221
Robert Buttery Div. Range Management U.S. Forest Service	Denver Federal Center Denver, CO 80225	234-4011 (closes 4:30 PM)
Glenn F. Carnahan, USDA-SCS Manager, Upper Colorado Environmental Plant Center	P. O. Box 1105 Meeker, CO 81641	878-5131
Edward B. Cattrell Colorado Mountain College	Leadville, CO 80461	486-2015 Ext. 35 or 23
Tom Eaman Soil Conservation Service	Rm. 309, 2490 W. 26th Ave., P.O. Box 17107, Denver, CO 80217	837-3167 (closes 4:00 PM)
James W. Echols Extension Seed Certification Dept. of Agronomy, C.S.U.	Ft. Collins, CO 80523	491-6202

Name and Affiliation	Address	Phone (office)
Martin R. Ekrem Environmental Products Division Conwed Corporation	5963 South Krameria Englewood, CO 80110	770-3311
Dr. John Ericson Mile-High Seeds Co.	Box 1988 Grand Junction, CO 81501	242-3122
Dr. James R. Feucht Extension Horticulturist C.S.U.	909 York Street Denver, CO 80206	355-8306
Franklin Friedenberger Arkansas Valley Seeds Co.	Box 270 Rocky Ford, CO 81067	254-7469
Patsy Goodman Colo. Dept. of Highways	4200 E. Arkansas Denver, CO 80222	757-9259
Wendell G. Hassell Plant Materials Specialist USDA - SCS	P.O. Box 17107 Denver, CO 80217	837-3167 (closes 4:00 PM)
Dr. Warren Keammerer S & K Associates	2865 Emerson Ave. Boulder, CO 80303	499-6695
Dean W. Kerkling Mountain Division Vail Associates, Inc.	Vail, CO 81657	476-5601 Ext. 513
J. B. Snobble Aspen Skiing Corporation	Aspen, CO 81611	925-1220
David Stevens National Park Service	Estes Park, CO 80517	586-2371
Mike Tupa Colo. Dept. of Highways	4200 E. Arkansas Denver, CO 80222	757-9259
Paul Wilderman Winter Park Recreational Assoc.	Winter Park, CO 80482	726-5514 255-7142 (Denver)

HIGH ELEVATION RECLAMATION NUTS & BOLTS

Honorable Beatrice E. Willard
Member, Council on Environmental Quality
Executive Office of the President

Soil is "worth its weight in gold." Its development is controlled by a complex of inorganic and organic processes interacting over time and building on each other. One hundred years are required for the formation of one inch of topsoil in Iowa, therefore it seems plausible that at least 500 to 1,000 years is a minimum time requirement to form an inch of tundra topsoil in the Front Range of the Colorado Rocky Mountains, where growth and decay processes are much slower and less prolific.

Tundra soil is a seed source of native plants, which are well adapted to the wide range of environmental variables in the alpine. Native species are a great resource, but are often overlooked by reclamationists. Pioneer plants native to the high elevation ecosystems are geared to colonizing and offer a natural diversity in composition, adaptability, germination time, and tolerance of a highly variable environmental complex. The contribution of natives to the reclamation effort is very valuable and they should be used rather than foreign exotics and domesticated strains. (No non-alpine plants survived beyond one season in the Trail Ridge Exclosures.) However, we still need to know how to provide more seed and plant materials, what to do that will make the natives even better colonizers, and to devise means to hold high elevation soils in place while colonization proceeds.

Is the transplanting of tundra and subalpine plants really impossible? Or do we need to be more persistent in promoting ecological solutions? Botanists and engineers with different expertise, have worked together on this problem after coming to appreciate the constraints on both sides. The Western Slope Gas Company line across Rollin's Pass in 1970 is an excellent example of what can be done in transplanting tundra. The sods placed on cut banks of Trail Ridge Road are also; they also indicate the slow rate of radial expansion. Reclamationists should really look into the transplantability of tundra turf. The short growing season of the alpine makes transplanting ideal as a head start for plants. The turf offers an intact, compact "erosion control device" with organics and microorganisms built in. Also, alpine turf is amazingly resilient to transplanting, as long as it is kept upright and moist (not wet).

Successional stages and snow accumulation patterns are the key to plant and animal distribution in the alpine. Differences in microclimate need to be closely observed and matched with vegetation patterns to indicate the proper species for transplanting to given sites, such as transplanting meadow plants into wet areas, not dry sites. In similar respects, developmental stages of vegetation can be utilized. Through the course of time, vegetation accumulates organic matter in the soil, altering it so that sites vary from one to the next in microclimate, soil, exposure and amount of competition.

Treeline delimits the interface between two major climate types of Earth -- the temperate and the arctic climates. These climates are vastly different; therefore the ecosystems evolving in them are very different. Tundra vegetation in the arctic climate has both a slower rate of growth and shorter growing season, and a correspondingly slow rate of soil forming processes. The greater extremes in climate pose the threat of "winter at anytime", severe drying, and freeze-thaw processes. Actually, winter endures for five months with no ambient temperatures above 32 degrees Fahrenheit. Snow-free areas become exposed to high winds and desiccation. Ambient temperatures of the short variable summer are all below 67 degrees Fahrenheit, but temperatures less than 32 degrees Fahrenheit, and accompanied by snow, are not uncommon. Alpine sunlight is intense.

Vegetation from cultured seeds planted in the alpine do not compete well with the natural vegetation and can succumb easily to the elements. The uniformity of the seed and vegetation provide no diversity to adapt to the wide range of seasonal differences. Also, few strains of cultured seeds come from alpine species.

To control soil erosion, vegetation must be established as quickly as possible. Viable seed in the top one inch of surface soil can germinate within 24 hours, but is susceptible to needle ice and desiccation. This hazard is not as great near borders of existing vegetation, but can be severe in areas of bare, dark soil, which have extreme radiant heat gain and loss.

To overcome many of the problems and hazards of revegetation and erosion control in the alpine, reclamationists should learn to read the landscape under all of its conditions. Examples of this method are observations made on tundra plots on Rock Cut areas and Forest Canyon Overlook on Trail Ridge for over 17 years, and other tundra plots on the Old Fall River Road at the west end of Trail Ridge.

Questions that we are trying to answer are: How long does it take to get natural reseeding on surfaces worn bare by human trampling? How rapidly do existing live plants expand into open sites? What stages of succession take place? What processes speed up and what slow down revegetation? Subalpine surfaces damaged by trampling recover almost totally from complete vegetation destruction within five years. Alpine surfaces take two to hundreds of times as long, depending on the amount of trampling and the type of stand. Can we reduce soil erosion? Perhaps we can feed the consumers as well with cultured plants? And is it worth it?

Are our environmental and economic objectives compatible? Its how we ask the question. If by environmental objectives we mean preservation in the status quo, and by economic objectives we mean wholesale exploitation. No they are not compatible. If we mean allowing society to pick up the tab for watersheds disrupted, wildlife habitat destroyed, soil eroded, and not transferring these costs to the creator of the disruption, then No.

But, if we recognize that a quality environment includes a viable economy and that economic development includes "harmonizing human activities" with ecosystem activities, Yes, our environmental and economic objectives are compatible.

In our history we have precedent for this in numerous areas:

1. carrying capacity of range
2. sustained yield logging and tree farms
3. managed wildlife and fisheries
4. conservation practices in resource development
5. cleanup of air and water

Fundamentally, we can't afford not to make these objectives compatible, as one supports the other.

But we have some investigations and calculations to make on what high elevation landscapes are doing for us that we do not have to pay for.

E. P. Odum has calculated Georgia salt marsh to be worth 25 to 40 times what developable land would be. We need to calculate values of alpine and subalpine ecosystems, based on all the jobs they do for us, as they exist.

With healthy ecosystems, our great nation can remain healthy and wealthy in the future. Without healthy ecosystems, we and the nation cannot remain healthy and wealthy.

RECLAMATION LAWS AS THEY AFFECT HIGH-ALTITUDE REVEGETATION

Gilbert F. Rindahl
Director of Mined Land Reclamation
Colorado Department of Natural Resources

EXISTING LAWS

Every mining operation in the state is covered to some extent by one of three statutes, but the requirements for revegetation and reclamation in general differ markedly from one statute to another. Two of the statutes have little consequence in regards to high-altitude revegetation. Underground coal mines are covered through the coal mine statutes, but because there are few high altitude underground coal mines, this law is of little importance at high altitudes. In addition, there appears to be little potential for high-altitude underground coal mines, although there is a slight possibility of this in Gunnison and Pitkin Counties, Colorado.

The Colorado Open Mining Land Reclamation Act covers strip coal, sand, gravel, quarry aggregate and construction limestone. Again there does not appear to be very many cases where this law would apply to high elevation operations. The few cases where it does apply are generally sand and gravel operations, particularly those that are crushing material from old placer mines. The potential application of this law to mining at high elevations is small because these areas generally have little strippable coal, aggregate or limestone.

The third law which covers all other mining activities, including metal mines and associated mills, does have jurisdiction in high elevations. Historically, much of the mining activity in Colorado has been above 9000 feet elevation. With increases in gold prices, there has been a great response to open old mines as well as to initiate new mines. Many of these mines are in the 9500 to 12,500-food range which includes the spruce-fir forest and alpine tundra vegetation zones.

EXTENT OF RECLAMATION REQUIREMENTS

For practical purposes, there is only one law that affects high elevation operations, and it will be the focus of this paper. This law requires only that the operator protect the land against erosion, landslides and floods. Only indirectly do aesthetics enter the picture, and revegetation is required only "if necessary and practical". In addition, planning can legally occur after the fact because the inspector is only required to inspect "the methods of stabilization and reclamation....employed in or on such areas...". The operator is not required to obtain a permit or even a departmental approval prior to beginning his operation.

The only tool for enforcement of the law is the agreement between the Commissioner of Mines and the operator. The agreement sets forth the work to be required to stabilize and reclaim the land. Agreements are satisfactory as long as the commissioner can get the operator to agree to do what is necessary in these difficult to reclaim areas. If the operator will not agree, a compromise must be established and such a compromise may be woefully deficient. Generally, it is believed that this law does not provide even the minimal tools for ensuring high-altitude reclamation of mined lands.

THE NEW RECLAMATION BILL

At present, House Bill 1065 is passing through the legislature. This new bill would consolidate the present three laws. It would provide considerably strengthened jurisdiction over mining and would improve the enforcement capability over high-elevation areas. The bill directs that reclamation return the land to a beneficial use rather than merely a control of erosion, landslides and floods. Revegetation standards are instituted and the operator must draft his plans in accordance with these standards. Permits must be obtained before initiating any operation. The decision to permit would rest with a board of seven members rather than one person, and has a provision for public input. The bill includes the capability for the Land Reclamation Board to close down an operator if he is operating without a permit.

In summary, the new bill, if it becomes law, would provide the state with a general tool with which to control reclamation of all mined lands and to have it done by means of standards rather than agreements.

REQUIREMENTS OF RECLAMATION SPECIALISTS

The real meat of a good reclamation program is to have a staff that realizes the needs and sensitivities of the land. This is of special importance in high-altitude revegetation. The specialists that work these areas must be well acquainted with the unique needs of spruce-fir forest and alpine tundra vegetation. Because of the short food chains, the rigorousness of the climate, the extreme slowness with which many of these areas recover from disturbance, and the general hypersensitive character of the vegetation, extreme caution must be exercised in allowing disturbances. Therefore, as part of our staff, we have employed and will continue to employ specialists in high altitude ecology and land utilization.

THE STATE'S NEEDS

It is becoming more and more apparent that the alpine areas are the most critical areas in the state. After a disturbance, the land may require hundreds of years to naturally revegetate. This is a time frame that is clearly unacceptable. The state needs information on every new technique that is being applied. There needs to be much research on methods of stockpiling, not only soil, but vegetation.

We need answers to these questions and to many more:

1. How do the native species regenerate and can the regeneration be accelerated and accomplished on a large scale?

2. What species can be used in revegetation and in what combinations?

3. What are the rates of natural reclamation of disturbed lands with respect to the degree of disturbance?

4. Can new mining methods be devised that virtually eliminate the surface disturbance?

Control of these lands can only come:

1. After we are able to accurately assess the severity of the impact of high altitude operations;

2. After we understand the environment in which we are trying to prevent irreparable harm; and

3. After we have the adapted plant materials available to adequately and permanently reclaim the affected lands.

*Editor's note: The new mined land reclamation bill referred to (HB1065) was signed into law by Governor Lamm in June, 1976.

ENVIRONMENTAL PROTECTION TECHNOLOGY AS A WAY OF TRAINING RECLAMATION PERSONNEL

Edward B. Cattrell
Colorado Mountain College, Leadville

There are many ways to approach the problem of training people to perform any given set of tasks, many ways to educate, and many ways to learn. The title of this segment of the workshop -- Environmental Protection Technology as a Way of Training Reclamation Personnel -- suggests two major points:

1. A comparison of various ways that one could go about learning the principles, techniques, and skills of land reclamation and,

2. How and why the Environmental Protection Technology/Land Rehabilitation program at Colorado Mountain College, Leadville, is designed like it is.

In the past, most land reclamation people have had some, if not all, of the following background characteristics:

1. An agricultural background.

2. A Bachelors Degree in agronomy, soil science, forestry, range management, or some associated field.

3. Often graduate work at the Masters and/or Doctoral level.

4. Varying levels of engineering skills.

5. Some sort of affiliation with either a university or a governmental agency (examples would be an extension specialist, a professor who consults on the side, or an SCS field man).

6. No formal training in land reclamation, per se, but acquired knowledge based upon research interest, a conservation ethic, and personal experience.

Historically, the number of these reclamation specialists was rather small -- with our frontier outlook, which prevailed for nearly two hundred years, putting grossly disturbed land surface back into a productive state was not one of our major concerns either as a culture or as a nation. We were much too involved in our patterns of progress to worry much about our leavings. Unfortunately, some segments of the society still see our world in the old frontier perspective. Fortunately, fewer people, over time, retain that viewpoint.

At the end of the 60's, with the enactment of the National Environmental Policy Act, much more emphasis was immediately placed on the reclamation of land surface disturbed by extractive industry. Prior to NEPA many states had legislation on the books but, in general, enforcement problems hampered implementation of existing law.

NEPA-69 did several things -- among these was a delineation of national policy with respect to environmental quality and at this point the education "industry" of the United States began to respond to the increased emphasis on environmental quality at several levels. Typical of the early exploratory work would be a secondary-school project in New Jersey which shifted the thrust of its Vocational Agriculture program from an unsuccessful one in production agriculture to an environmentally oriented program ranging from fish pond management and wildlife habitat improvement to outdoor recreation leadership. Other programs at various levels were initiated -- community and junior college programs in environmental sciences served as feeder systems to new bachelors degree programs at colleges and universities. Advanced degree programs, usually at the Master's level, also began to show up here and there in various university catalogues. By and large, these were couched in rather general terms, holding to traditional kinds of requirements and, in some cases, designed to catch the bandwagon effect of the "ecology movement" of the late sixties and early seventies. The foregoing is not stated to imply that there was or is anything ethically or educationally "wrong" with such general programs. They do what they are designed to do -- mention of them is made only to point up differences, not to imply judgements.

In that period known as the early 70's, three community colleges in three different states began, independently, and initially without any awareness of what the others were planning, to put together a new sort of two-year curriculum.

The new curricula go by three different titles: Mined Land Reclamation, Reclamation Technology, and Environmental Protection Technology/Land Rehabilitation. They are common in length (two years of specialized training), common in general goals (vocational level education and training resulting in entry-level technician jobs for their graduates in some aspect of land reclamation), and common in size (as far as total numbers of students enrolled).

They also appear to have roughly the same attrition rate over their two-year length.

The three schools share additional commonalities too:

1. Each school is geographically located in an area where extractive industry provides the major portion of the economic

base. The Western Kentucky Center and Belmont College in southern Ohio are in coal country. Colorado Mountain College, Leadville, is, of course, located in the middle of this state's hard-rock mining activity.

2. Each school is relatively small, as junior colleges go, enabling a tight student-faculty relationship, small classes, and a personal education. Educational theorists tell us this is great. On the negative side, however, another function of extremely small scale is the tendency toward the creation of disciples complete with all the biases and inadequacies of their one or two program-core teachers.

After the inception of the EPT/Land Rehabilitation program late in 1972, we at Colorado Mountain College became aware of our counterparts in Ohio and Kentucky and we have, to a limited degree, since exchanged pleasantries and information by mail.

With that bit of backgrounding out of the way, we can now get down to what is happening in the EPT program up on top of the hill at Leadville, what an EPT graduate is theoretically able to do, and what needs to be done to make the program more effective as far as training in reclamation for industrial and agency needs is concerned.

Environmental Protection Technology students are generally people who are environmentally aware long before they ever arrive on the Leadville campus of Colorado Mountain College. They are a bit older than the average entering college freshman. Many of them have had other kinds of college experiences -- some of them successful, some not so successful. Many current students are veterans.

The program that these people go into is designed to: (1) give a solid base in the sciences upon which to build; (2) and provide a set of specialized techniques and skills which allows them to enter with some degree of confidence into the field of land rehabilitation.

What sorts of basic science grounding are referred to: Environmental Protection Technology freshmen pick up three quarters of a low-theory/high-application mix of plant science, plant propagation, and applied vegetation management as their introduction to the living component of the revegetation business. Additionally, one quarter of general plant taxonomy also builds depth in the plant science sequence. Two quarters of chemistry are coupled with one quarter each of introductory soils, soil chemistry, and plant-soil-water relations to build in an understanding and a practical working knowledge of the soil complex. Stuck into this mix of plant and soils classes are numerous field-oriented experiences such as vegetation mapping, plant collection and identification, field soil-collection and analysis, various trips to investigate different biotic communities, and opportunities for field integration of classroom and laboratory encountered information.

Since the Colorado Mountain College program must condense itself into a two-year time span, all course work is geared toward application. Additional basic sciences -- physics, mathematics, geology -- are included in the first year's work. A once-over lightly course of land rehabilitation technique fills out preparation for a student's summer internship.

During the interim summer between the first and second years, students are placed as interns with either resource management agencies of Federal or State government or with industrial companies actively engaged in revegetation work. Some of these internships currently being either considered or pursued for the coming summer of 1976 include revegetation work at the new Mary Jane expansion at Winter Park, vegetation analysis in the back country of the Gore Range, range management studies on the Arapahoe-Roosevelt National Forest, revegetation studies with some of the major coal mines in southern Montana and north-eastern Wyoming, soils studies at the Fryingpan/Arkansas Project at Twin Lakes, Colorado, and watershed and snow studies on Independence Pass between Twin Lakes and Aspen. Additionally, monitoring and data collection from our campus' sets of High Altitude Revegetation plots also provides one intern with a summer work experience.

Following the interim summer internship, the Environmental Protection Technology student returns to the program to pick up surveying, aerial-photo and map interpretation, equipment operation, pollution detection and control, drafting, a general ecology course, a course in waste disposal systems, and a second intensified course in land rehabilitation techniques. He or she works on baseline data collection and on-site reclamation projects. Each student spends some time working with the on-campus plot system, collects data, and prepares technically competent reports on his findings. Since Colorado Mountain College, Leadville, is a small campus and since the program has a small number of sophomore students, these experiences lend themselves to an almost tutorial situation and allow each potential graduate to be shepherded along. This allows the shoring up of weak spots and the filling in of gaps that, until this point, may have remained unnoticed.

So what can an EPT trained person do for a potential employer? We can only theorize here because we have no graduates to date upon which to base any postulations -- our first graduating class will not hit the real world until June, 1976. But here's how it's "supposed to work".

An Environmental Protection Technology graduate from Colorado Mountain College is first trained as a Land Rehabilitation Technician. He can set up base-line studies, collect base-line data, do land surveying and aerial photograph interpretation from a series of data sources. He has had a familiarization with equipment operation and, while not an accomplished operator of heavy equipment, he is not a liability on a job-site utilizing large machinery. His real strengths are in soils work, revegetation and vegetation management, test-plot system design, and use of reclamation technique. Depending on the individual, he can function as a crew-leader or in other "slightly-supervisory" roles.

As secondary skills, the EPT graduate has pollution-detection and monitoring experience, can use a wide variety of laboratory instrumentation, and has proved himself as a person with an interest in the area of ecological work who is definitely trainable -- he may or may not have the expertise required to do a specific job, but he does have a broad background of quite specialized knowledge upon which to draw and the ability to learn. Again, the depth of background retained and the speed with which new applications of technique are picked up depend, as does most everything else in this life, upon the individual.

REGENERATION OF FOREST LANDS AT HIGH ELEVATIONS IN THE CENTRAL ROCKY MOUNTAINS

Frank Ronco
Rocky Mountain Forest and Range Experiment Station
Fort Collins, Colorado

When Dr. Brown invited me to present a paper on regeneration of trees and shrubs at high elevations, my immediate thoughts were that preparation would be relatively easy, particularly since my speciality is forest regeneration. However, it soon became apparent that compressing years of experience and training into a half-hour presentation before an audience with widely varied backgrounds would not be the simple task I had imagined.

I debated whether the topic of forest regeneration should be treated in a general manner or in considerable detail, describing each step in the regeneration procedure. But, I concluded that the former would contribute little to a workshop session, while the latter has already been presented in a number of excellent publications on tree planting in the central and southern Rocky Mountains. Although a successful regeneration program obviously requires that correct planting techniques be applied, my observations have shown that regeneration success has oftentimes been greater when land managers were aware of the reasons leading to the development of such planting techniques. I believe that regeneration, particularly at high elevations, can be enhanced when the land manager has a basic understanding of the fundamental physicological requirements and ecological principles of the species he is dealing with, and when he is aware of the relationship of such requirements and principles with the most critical factors and problems associated with high elevation environments.

With this philosophy in mind, I would like to approach the topic of regeneration at high elevations by emphasizing the research being conducted on Engelmann spruce at the Rocky Mountain Forest and Range Experiment Station.

FOREST ECOLOGY

The lower limit of growth of major tree species in the central and southern Rocky Mountains is approximately 6,000 feet, while the upper limit approaches 12,000 feet. Because of this wide elevational range, tree species exhibit a vertical distribution associated with habitat conditions. For example, forest sites at low elevations in the montane zone--which extends from about 6,000 to 9,500 feet--are typically hot and dry, but they become progressively wetter and cooler as elevation increases, particularly in the subalpine zone abve 9,500 feet (slide 1). Ponderosa pine ia associated with the warm, dry sites of the montane zone, whereas Engelmann spruce and subalpine fir are the most abundant and widespread species of the subalpine zone, growing on the coolest and wettest sites. Spruce and fir are the upper limit species in the central and southern Rocky Mountains and grow at elevations ranging from 10,000 feet to timberline at 11,000 to 12,000 feet. Elsewhere over their range, as illustrated here for the Inland Empire, other species may be climax and occupy higher and cooler elevations.

Other principal tree species found in the subalpine zone of the central Rocky Mountains are lodgepole pine, bristlecone pine, limber pine and aspen, with lodgepole and aspen generally occupying the warmer and drier sites at successively lower elevations below the wetter spruce-fir type. Although aspen makes its best development at lower elevation sites similar to those occupied by the interior Douglas-fir type, it is an important component of the ecosystem at higher elevations. The ecological position of bristlecone and limber pines is not as well defined or understood as that for other species. Both species grow to timber line, but generally bristlecone is found at higher elevations in the subalpine zone, whereas limber pine is more common at the extreme lower elevations of the zone. Both species, however, possess similar characteristics in that they are found on poor sites, especially dry, windswept ridges.

Spruce-fir stands are climax and perpetuate themselves by reproducing under their own canopy. They will occupy the site until destroyed by some external force such as fire, insects or logging. Aspen, bristlecone pine, limber pine and lodgepole pine are pioneer species and are usually the first trees to invade disturbed sites. However, these successional species are unable to reproduce under their own canopy, as illustrated in this lodgepole pine stand, and are replaced by spruce and fir. In some instances, soil conditions may allow these seral species, particularly aspen and lodgepole pine, to form stable subclimax communities. Natural or man caused disturbances at high elevations alter the microenvironment so drastically that 200-300 years may elapse, depending on the pathway followed by succession, before the area is regenerated by climax vegetation. For example, if aspen or lodgepole pine were present in the original stand, then the spruce-fir climax can be expected in perhaps 30-50 years. But if these tree species are absent, and grasses or sedges occupy the site following disturbance, then several centuries may elapse before climax vegetation becomes established. For example, this high-elevation burn on Vail Pass occurred just before the turn of the century, and as you can see, regeneration of the area is far from complete.

The role of different tree species in succession is a function of their tolerance, which may be defined as the ability to reproduce and grow in shade. Climax species such as Engelmann spruce and subalpine fir are tolerant trees and may be classed as shade plants--they make their best growth in partial shade. Lodgepole pine, bristlecone pine, limber pine and aspen, on the other hand, are intolerant species and are considered sun plants--they grow best in full sunlight. A knowledge of the tolerance rating of tree species can help the land manager to select the trees best suited for regenerating a particular site. For example, subalpine sites fully exposed to sunlight generally limits choice of planting stock to intolerant species or sun plants, the pioneer species. In contrast, if planting sites have a cover of shrubs or inert objects such as logs or stumps that provide shade for seedlings, then the logical choice of species would be tolerant, shade-adapted spruce or fir.

Similarly, the ecological position occupied by different species can also serve as a guide for selecting species to plant. Lodgepole pine or aspen would be most suitable for planting in the subalpine zone on warm, dry sites at elevations below about 10,000 feet. At higher elevation dry sites, especially rocky ridges, bristlecone and limber pines would probably be the best species to plant. In contrast, the wetter and cooler sites at elevations above 10,000 feet should be planted with Engelmann spruce or subalpine fir. If esthetics or uses other than maximum timber growth are the primary concerns of the land manager, then the choice of species to plant at a particular elevation is less restrictive. Thus, Lodgepole pine which is adapted to warm sites at lower elevations near 9,500 can be successfully planted at higher elevations, providing planting sites are located on south or west facing slopes.

As a general rule, species selected for planting should be native to the planting site. While such a rule would, for example, prevent offsite planting of ponderosa pine in the spruce-fir zone, the presence of a species on a site prior to disturbance does not signify that regeneration can always be easily accomplished. Drastic changes in the microenvironment may have occurred as a result of the disturbance, so that extraordinary means must be taken to insure regeneration success.

RESEARCH

The complexity and difficulty of regenerating high elevation stands can perhaps best be illustrated by the work done with Engelmann spruce at the Rocky Mountain Station. When stands of tolerant spruce, which reproduces under its own canopy, are harvested for timber or other purposes and slash is destroyed by piling and burning to reduce the bark beetle hazard, or to reduce the visual impact of heavy slash accumulations, the microenvironment is altered drastically.

Initial attempts to regenerate spruce by planting cutover areas were not successful. Early studies showed that few seedlings planted in full sunlight died during the first growing season. Most seedlings died during the first winter. Furthermore, a great deal of the mortality during the second summer could easily have been attributed to overwinter losses, since seedlings emerged from winter in such poor condition that survival was questionable. Although lodgepole pine is not a component of spruce-fir stands at higher elevation, it was included in research studies because pine seedlings survived better than spruce in early plantations. Concurrent plantings of the two species also allowed a comparison between the behavior of shade tolerant and intolerant species. Mortality of lodgepole pine seedlings in experimental plantings was less than one-half that of spruce.

It was also learned from these early studies that shade increased survival of spruce, but had no effect on pine. After two growing seasons, total mortality of unshaded spruces was 85 percent. The effect of shade on seasonal mortality of Englemann spruce could conceivably lead to conclusion that shading altered the winter environment to the benefit of seedlings. Such was not the case, however, since seedlings were shaded only during the growing season. Shade was removed at the onset of winter so that all seedlings were fully exposed to wintertime conditions. Therefore, it appears that the physiological response of seedlings to shade during the growing season enables them to survive better overwinter. Apparently, seedlings incur irreversible injury during the preceding growing season.

Sawn-cedar shingles were used in the studies because of convenience and uniformity of treatment. Note the absence of seedlings that had originally been planted in unshaded rows on either side of the shaded row. Also, particularly note the healthy appearance and dark-green foliage of seedlings under the shingles. In contrast to vigorous, healthy, shaded seedlings, the foliage of a typical open-grown spruce seedling does not have normal coloration. Foliage older than one year is yellow, whereas current growth is normal in color early in the growing season. By fall it also turns yellow, however.

SOLARIZATION

The chlorotic appearance of seedlings exposed to intense light is a symptom of solarization resulting from the destruction of chlorophyll. Solarization--also known as light injury, light inhibition or photo-oxidation--is the phenomenon in which extremely high light intensities cause a reduction in the photosynthetic rate of plants, and which may also cause death in extreme cases.

Seedlings growing at high elevations in the central Rocky Mountains are exposed to radiation levels considerably higher than at sea level. For example, radiation at sea level in temperate climates might be near 1.2 Langleys on a clear summer day. Radiation at high-elevation forested sites, in contrast, reaches 1.9 Langleys, and often exceeds the solar constant of 2.00 Langleys when radiation is reflected by scattered cumulus clouds. Although total radiation increases with increase in elevation, perhaps of greater importance with respect to tree growth is the increase in the visible portion of the spectrum, since these wave lengths are responsible for solarization. Light intensity at sea level on a clear day is about 9,000 to 10,000 foot candles. At high elevations in the Rocky Mountains, however, light intensity on a clear day will reach 13,000 foot candles by 8:00 A.M. and remain at that value with little variation until the sun begins to set. When a scattered cumulus cloud cover is present, visible light intensities will reach 16,000 to 17,000 foot candles for periods up to several minutes.

Accumulated evidence from our early studies leads us to believe that the primary cause of mortality of planted Engelmann spruce seedlings is due to light injury or solarization. Drought, frost heaving and animal depradations, while killing some seedlings, were not major causes of death.

The sensitivity of spruce seedlings to intense light is further illustrated by the following three slides of the same seedling taken 5 years after planting. The entire seedling was in full shade during midday for the first few years after planting. Subsequently, the terminal leader and lateral branches grew beyond the protection of the shingle and were fully exposed to sunlight for the entire day. The lower and central portion of the foliage, however, was still shaded except for early morning and late afternoon. Sunlit foliage was severely damaged by solarization, whereas shaded foliage was not injured as is evident when the shingle is removed and the seedling is viewed from different aspects. It should be emphasized that during all years studies were in progress, no evidence of solarization was observed in any lodgepole pine plantings, even though pine seedlings in some plantations were intermixed with spruce seedlings.

The different behavior of the two species in response to intense light is more likely related to their shade tolerance. The photosynthetic curves of Engelmann spruce and lodgepole pine seedlings are quite typical of shade and sun plants, respectively. The photosynthetic mechanism of intolerant lodgepole seedlings does not appear to reach light saturation even at high light intensities of 12,000 foot candles. On the other hand, tolerant spruce seedlings reach saturation at low light intensities near 3,000 to 5,000 foot candles. Under field conditions, therefore, spruce seedlings are almost continuously exposed to light intensities that are 3 to 5 times higher than the saturating intensity. Conditions thus appear most favorable for solarization, since it occurs at light intensities above saturation and begins within a short time following saturation. The lower photosynthetic rate of open-grown spruce seedlings compared to that of shade-grown spruce seedlings at all light intensities up to 12,000 foot candles suggests that the photosynthetic mechanism is disrupted by intense light. In fact, the reduction of photosynthesis under high light intensities is frequently used to identify the phenomenon of solarization. The curves also suggest that spruce seedlings grown in full sunlight do not adapt to the higher light intensities, otherwise the photosynthetic curve for open grown spruce seedlings should have resembled that of lodgepole pine.

Our research has demonstrated that shading planted spruce seedlings enables them to survive by reducing intense light, a necessary condition for solarization. However shade may also affect solarization by influencing internal plant conditions which can enhance or trigger the phenomenon. For example, high leaf temperatures, plant water stresses, and low food reserves have been associated with solarization. Although the relationship between these factors and solarization in spruce seedlings is not yet fully understood, shade would tend to create more favorable temperature regimes and internal water balances. Depletion of food reserves may also be alleviated by shading but in a less obvious manner than with other factors. Although spruce grows in cold habitats, new growth is extremely sensitive to frost, which can be expected to cause injury in plantations in most years. Frost injury, such as illustrated from a mid-July nighttime freeze, can be nearly eliminated by blocking radiant heat loss from the seedling and surrounding soil to the nighttime sky. Preventing frost injury indirectly maintains higher levels of food reserves in seedlings, since new shoots, which depend primarily on stored reserves for growth, stay alive to replenish photosynthates used in their initial development.

PLANTING GUIDE

Fortunately, a canopy of either live vegetation or inert objects that reduces intense light and subsequent solarization, also tends to protect seedlings against environmental factors that are conductive to solarization, or which in themselves adversely affect survival. Consequently, the need for protection has been strongly emphasized in a guide for planting Engelmann spruce in the central and southern Rocky Mountains. The guide has led to the current practice of planting only in acceptable planting spots, which may be defined as microsites located on the north and east side of down logs, stumps, or slash, and lying within the shadow cast by such material. In burned or logged areas, acceptable planting spots created by debris are usually abundant and randomly distributed, so that the resulting plantation acquires the spatial characteristics of natural reproduction. Where management objectives require more uniform spacing or higher densities, shading material may be redistributed. Areas critically in need of regeneration but lacking acceptable planting spots, may require more extreme measures to provide protection, even to the extent of manually transporting and arranging small logs to create suitable microsites.

SHRUB ECOLOGY

The tendency of Engelmann spruce to become established and survive better in microsites where light is subdued has also been observed under a variety of natural conditions. For example, spruce regenerates well under lodgepole pine and aspen canopies. It has also been found to reproduce under shrubs such as potentilla and willow. In one case, four seedlings ranging from 1 to 4 feet tall were found in one small clump of willows. In another instance, no seedlings could be located on exposed ground in a large opening of fire origin. However, the habitat created by a clump of willows in the opening provided a microsite under its branches for seven seedlings up to 1 foot in height. One seedling was just visible under the outer perimeter of the clump, while the remainder could not be readily seen until the branches were raised.

This capability of shrubs to act as a nurse crop for conifers is, perhaps, the ultimate function of such vegetation in regenerating forest lands at high elevations. Such a role should not be surprising, however, since a number of ecological studies have shown that shrubs frequently are a temporary stage in forest succession, immediately preceding establishment of the climax tree species. Shrubs would not only provide a suitable habitat for shade-tolerant trees by reducing intense light and subsequent solarization, but they would also tend to create a more favorable environment for trees in general. By reducing solar radiation and wind movement on open slopes, particularly those facing south and west, shrubs would ameliorate the harsh environment so that a more mesic habitat would be created.

Forest regeneration in some areas, particularly where shingles are impractical or where logs and stumps are not available to provide suitable microenvironments, may depend on our ability to regenerate shrubs that can function as a nurse crop. Unfortunately, research on artificial regeneration of shrubs at high elevations in the central Rocky Mountains is practically non-existent. Other than a limited study in 1938 by Harrington, who unsuccessfully seeded six species of shrubs in Rocky Mountain National Park, there does not appear to be any research that is directly applicable to conditions in the high mountains of central Colorado.

However, the same ecological principles that led to the formation of guidelines for selection of tree species are also applicable to shrub regeneration. Thus, shrubs selected for planting should be those that normally grow within the vegetation zone in which the regeneration project is located. For example, mountain mahogany and bitterbrush, which are usually found in the mountain brush and ponderosa pine-Douglas fir zones below 8,500 feet, should not be selected for planting in the spruce-fir zone above 10,000 feet. Many other shrub species, in contrast, have a wide elevational range; russet buffaloberry, for example, grows well at 7,500 or 11,000 feet. In this latter instance, however, one should not assume that seeds collected at one elevation will germinate and grow well at a widely different elevation. Since plants adapt to environmental conditions in which they have developed, regeneration success will generally be higher when plant propagation material is collected from areas having soil and climatic conditions similar to those of the planting site.

In contrast to the readily available data for forest trees, comparable information regarding tolerance of shrubs is lacking. Consequently, in an attempt to provide the land manager with a functional guide, I have assigned tentative shade tolerance ratings to shrubs commonly associated with different forest zones in the central Rocky Mountains. The ratings were based primarily on personal observation and consultation with scientists at the Rocky Mountain Forest and Range Experiment Station, but some published information was also considered. Since shrubs generally comprise a seral stage in succession, it would be expected that most of them would be classed as intolerant or sun-plants, making their best growth and development in full sunlight. However, a few of the more tolerant or shade-adapted species grow well under a canopy of trees and form part of the understory in climax forests. Of the forty-six shrubs listed, about two-thirds were rated intolerant, whereas the remainder exhibited varying degrees of tolerance to shade. This listing should be of help in selecting the kind of shrubs to plant. For example, intolerant species such as willows or most currants would be suitable shrubs to plant on bare, exposed slopes since they grow best in full sunlight. In contrast, russet buffaloberry or mountain snowberry, which are intermediate in tolerance, would be good choices to plant in the partial shade of open forest stands. Similarly, grouse whortleberry--a low growing very tolerant shrub--would be an excellent choice to plant in glade forests located on ski areas.

Since techniques for regenerating shrubs have not been developed for the central Rocky Mountains, land managers must rely on personal experience and research conducted elsewhere. Plummer et al. (1968) have published an excellent guide on shrub regeneration in the intermountain region. Although their work is primarily concerned with restoration of big game ranges at lower elevations in Utah, it should be helpful in regenerating devastated lands elsewhere. It provides practical information on all aspects of shrub regeneration from seed collection to plantation care after establishment

LIST OF SLIDES SHOWN AT WORKSHOP PRESENTATION OF PAPER

Slide 1. Relative ecological position and habitat condition of some major tree species in the Rocky Mountains and Inland Empire. Trees are listed, as follows, in the usual order in which the species are encountered with increasing elevation from lower to upper timberline: ponderosa pine, Douglas fir, lodgepole pine, western whitepine, Engelmann spruce, subalpine fir and whitebark pine. Habitat conditions range from warm and dry for ponderosa pine (lower tree limit) to cold and wet whitebark pine (upper tree limit).

Slide 2. Interior of a virgin spruce-fir stand which is characterized by an understory of tree reproduction.

Slide 3. Interior of a mature lodgepole pine forest illustrating the characteristic absence of a tree seedling story.

Slide 4. Successional pathways are illustrated for re-establishment of a climax spruce-fir forest following destruction of the original forest cover by fire.

Slide 5. An 1890's burn on Vail Pass, Colorado, illustrates slowness of regeneration by climax tree species during succession following disturbance by fire.

Slide 6. Shade tolerance of some commercial timber species:

Intolerant	Moderately Tolerant	Tolerant
Lodgepole pine	Douglas-fir	Englemann spruce
Ponderosa pine	Western white pine	Subalpine fir
Bristlecone pine		Western hemlock
Limber pine		
Aspen		

Slide 7. Refer to Slide No. 1.

Slide 8. Mature spruce-fir stand prior to harvesting.

Slide 9. Clearcut spruce-fir stand following bulldozer piling and burning of slash.

Slide 10. Slash windrowed for burning in a cutover block of virgin Engelmann spruce.

Slide 11. Percent seasonal mortality of unshaded spruce and lodgepole pine seedlings following planting:

1st Summer	1st Winter	2nd Summer	2nd Winter	3rd Summer	3rd Winter	4th Summer
pine						
1	10	9	3	2	1	1
spruce						
2	25	13	6	5	9	4

S Slide 12. The effect of shade on planted Engelmann spruce seedlings is illustrated by seasonal mortality (percent dead seedlings.)

Treatment	1st Summer	1st Winter	2nd Summer
Shaded	4	16	5
Unshaded	12	56	17

Slide 13. Sawn-cedar shingles set in the soil on the south side of seedlings provide shade as illustrated by a row of 10 shaded spruce seedlings spaced 2 feet apart.

Slide 14. A typical open-grown Engelmann spruce seedling with chlorotic (yellow) foliage.

Slide 15. Mortality of planted spruce seedlings attributed to solarization (79%), gophers (13%) and other (8%), including frost heaving, trampling, snow mold and drought.

Slides 16, 17 and 18. The first slide in this series shown a spruce seedling shaded by a shingle, while the remaining slides are side and top views of the same seedling with the shingle removed. The series illustrated that chlorosis develops in sunlit branches extending beyond the protection of the shingle, but shaded foliage remains green.

Slide 19. Photosynthetic rates of potted planting stock grown for 4 months under different treatments following lifting from the nursery were as follows:

Species and Treatment	Foot Candles of Light (x 1,000) 1	3	5	7	12
		mg CO_2/min/cc of foliage			
Open-grown spruce	.006	.017	.019	.020	.021
Shaded spruce	.012	.023	.027	.027	.027
Open-grown pine	.101	.021	.031	.035	.041

Slide 20. Dead current growth on leader and all lateral branches of an established Engelmann spruce seedling illustrates the damaging effect of a July nighttime freeze about 7 weeks after buds broke dormancy.

Slide 21. Cull material left after logging a high-elevation burn provides a sufficient number of shaded planting spots for Engelmann spruce seedlings to adequately restock the area.

Slide 22. A planted spruce seedling is shaded by small logs that were manually transported to the planting site and arranged to reduce solar radiation.

Slide 23. Reforestation of a subalpine grass-land site was accomplished by planting spruce in protected spots created by small logs which were transported into the area and spaced at regular intervals.

Slides 24, 25, 26 and 27. Engelmann spruce regeneration is shown under a canopy of lodgepole pine, aspen, potentilla and willow, respectively.

Slides 28, 29 and 30. This series of slide illustrates the shade requirements of Engelmann spruce under natural conditions. A moderate cover of willows and other vegetation in an opening created by fire is shown in the first slide, but no seedlings were present on mineral soil exposed to direct sunlight. In the second and third slides, however, several seedlings were found under the branches of a willow clump which was visible in the first slide.

REFERENCES

Barth, R. C. 1970. Revegetation after a subalpine wildfire. Master of Science Thesis, Colo. State Univ., Fort Collins, 142 p.

Costello, D. F. 1954. Vegetation zones in Colorado. iii - x pp. In Manual of the plants of Colorado. H. D. Harrington. Sage Books, Denver, Colo. 666p.

Daubenmire, R. F. and A. W. Slipp. 1943. Plant succession of talus slopes in northern Idaho as influenced by slope exposure. Tarrey Bot. Club. Bull. 70:473-380.

Dix, R. L. 1974. Regional ecological systems of Colorado: a handbook. Environ. Resour. Center, Colo. State Univ. Fort Collins, Colo.

Dixon, H. 1935. Ecological studies on the high plateaus of Utah. Bot. Gaz. 97:272-320.

Graybeal, N. 1973. An analysis of vegetation on ski slopes at the Winter Park Ski Area. Master of Science Thesis, Colo. State Univ., 108 p.

Harrington, H. D. 1946. Results of a seeding experiment at high altitudes in Rocky Mountain National Park. Ecology 27:375-377.

Harrington, H. D. 1954. Manual of plants of Colorado. Sage Books, Denver, Colo. 666 p.

Larsen, J. A. 1929. Fires and forest succession in the Bitterroot Mountains of northern Idaho. Ecology 10:67-76.

Moir, W. H. 1969. The lodgepole pine zone in Colorado. Am. Midl. Nat. 81:87-98.

Patten, D. T. 1963. Vegetational pattern in relation to environments in the Madison Range, Montana. Ecol. Mongr. 33:375-406.

Plummer, P. A., D. R. Christensen, and S. B. Monsen. 1968. Restoring big-game range in Utah. Dep. Nat. Resour., Utah Div. of Fish and Game. Publ. 68-3, 183 p.

Ronco, F. 1972. Planting Engelmann spruce. USDA For. Serv. Res. Pap. RM-89, 24 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Ronco, F. 1972. Planting Engelmann spruce. A field guide. USDA For. Serv. Res. Pap. RM-89A, 11 p. Rocky Mt. For. and Range Exp. Stn.

Schubert, G. H., R. W. Pearl and L. J. Heidmann. 1969. Here's how: A guide to tree planting in the southwest, USDA For. Serv. Res. Pap. RM-49. 16 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Society of American Foresters. 1954. Forest cover types of North America (exclusive of Mexico). Soc. Am. For., Wash., D.C. 67 p.

Stahelin, R. 1943. Factor influencing the natural restocking of high altitude by burns by coniferous trees in the Central Rocky Mountains. Ecology 24:19-30.

U. S. Department of Agriculture. Forest Service. 1937. Range plant handbook. U.S. Dep. of Commer. Natl. Bur. Stand. Inst. Appl. Technol. n.p.

U. S. Department of Agriculture. Forest Service. 1965. Silvics of forest trees of the United States. USDA Agric. Handb. 271, 762 p.

U. S. Department of Agriculture. Forest Service. 1974. Seeds of woody plants in the United States. USDA Agric. Handb. 450, 883 p.

Wirsing, J. M. 1973. Forest vegetation in southeastern Wyoming. Master of Science Thesis, Wash. State Univ., Pullman 170 p.

Vegetation Zones and Commonly Associated Shrubs in the Central Rocky Mountains, With Tentative Shade Tolerance Ratings and Elevational Distributions[1/]

Species	Tolerance[2/]	Elevation (feet x 1,000)[3/]
Mountain Shrub Zone (6,000 - 8,500 feet)		
Common serviceberry (*Amelanchier alnifolia*)	intermediate	5 -10
Carruth sagebrush (*Artemesia carruthii*)	intolerant	5.5- 9.5
Big sagebrush (*Artemesia tridentata*)	intolerant	4.5- 9
Fendler ceanothus (*Ceanothus fendleri*)	intolerant	5.5- 9
True mountain-mahogany (*Cercocarpus montanus*)	slightly tolerant	4 - 8.5
Rubber rabbitbrush (*Chrysothamnus nauseosus*)	intolerant	5 - 9
Douglas rabbitbrush (*Chrysothamnus viscidiflorus*)	intolerant	5 - 9
Black chokecherry (*Prunus virginiana melanocarpa*)	intolerant	4.5- 9
Bitterbrush (*Purshia tridentata*)	intolerant	5 - 8
Gambel oak (*Quercus gambelii*)	slightly tolerant	4 - 8.5
Skunkbush (*Rhus trilobata*)	intolerant	3.5- 9
Woods rose (*Rosa woodsii*)	slightly tolerant	3.5- 9
Mountain snowberry (*Symphoricarpos oreophilus*)	intermediate	5.5-10
Ponderosa pine-Douglas-fir Zone (6,000 - 9,000 feet)		
Common serviceberry (*Amelanchier alnifolia*)	intermediate	5 -10
Bearberry (*Arctostaphylos uva-ursi*)	moderately tolerant	6 -10
Fringed sagebrush (*Artemesia frigida*)	intolerant	4.5-10
Big sagebrush (*Artemesia tridentata*)	intolerant	4.5- 9
Bog birch (*Betula glandulosa*)	slightly tolerant	7.5-11
River birch (*Betula occidentalis*)	slightly tolerant	5 - 9
Fendler ceanothus (*Ceanothus fendleri*)	intolerant	5.5- 9
True mountain-mahogany (*Cercocarpus montanus*)	slightly tolerant	4.5-10
Red-osier dogwood (*Cornus stolonifera*)	slightly tolerant	4.5-10
Ocean-spray (*Holodiscus dumosus*)	moderately tolerant	5.5-10
Shrubby cinquefoil (*Potentilla fruticosa*)	slightly tolerant	7 -11.5
Black chokecherry (*Prunus virginiana melanocarpa*)	intolerant	4.5- 9

Ponderosa pine-Douglas-fir Zone (Continued)		
Bitterbrush (*Purshia tridentata*)	intolerant	5 - 8
Wax currant (*Ribes cereum*)	moderately tolerant	4 -11
Willow (*Salix* spp.)	intolerant	3.4-13
Snowberry (*Symphoricarpos occidentalis*)	intermediate	3.5- 8.5
Subalpine Zone (9,000 - 11,500 feet)		
Aspen Stands		
Creeping hollygrape (*Mahonia repens*)	tolerant	5.5-10
Black chokecherry (*Prunus virginiana melanocarpa*)	intolerant	4.5- 9
Whitestem gooseberry (*Ribes inerme*)	slightly tolerant	5 -11
Woods rose (*Rosa woodsii*)	slightly tolerant	3.5- 9
Red-berried elder (*Sambucus pubens*)	intolerant	8 -12
Mountain snowberry (*Symphoricarpos oreophilus*)	intermediate	5.5-10
Lodgepole pine Stands		
Mountain alder (*Alnus tenuifolia*)	slightly tolerant	5 -10
Waxflower (*Jamesia americana*)	slightly tolerant	5.5-10
Common juniper (*Juniperus communis*)	intermediate	5 - 7
Twin-flower (*Linnaea borealis*)	tolerant	8.5-11
Bearberry honeysuckle (*Lonicera involucrata*)	moderately tolerant	7 -11.5
Gooseberry currant (*Ribes montigenum*)	intolerant	7.5-11.5
Prickly rose (*Rosa acicularis*)	slightly tolerant	4.5-10
Red raspberry (*Rubus strigosus*)	moderately tolerant	5.5-11
Willow (*Salix monticola*)	intolerant	7 - 9
Willow (*Salix pseudocordata*)	intolerant	5.3- 9.5
Russett buffaloberry (*Shepherdia canadensis*)	moderately tolerant	7.5-11.5
Dwarf blueberry (*Vaccinium caespitosum*)	moderately tolerant	8.5-12
Myrtle blueberry (*Vaccinium myrtillus*)	moderately tolerant	8 -12
Grouse whortleberry (*Vaccinium scoparium*)	tolerant	8.5-11.5

Spruce-fir Stands		
Silver sagebrush (*Artemesia cana*)	slightly tolerant	5 -10
Rubber rabbitbrush (*Chrysothamnus nauseosus*)	intolerant	9 - 9
Douglas rabbitbrush (*Chrysothamnus viscidiflorus*	intolerant	5 - 9
Common juniper (*Juniperus communis*)	intermediate	5 - 7
Black chokecherry (*Prunus virginiana melanocarpa*)	intolerant	4.5- 9
Bitterbrush (*Purshia tridentata*)	intolerant	5 - 8
Prickly currant (*Ribes lacustre*)	slightly tolerant	8 -10
Thimbleberry (*Rubus parviflorus*)	moderately tolerant	7 -10
Bebb willow (*Salix bebbiana*)	intolerant	5 - 9
Wolfs willow (*Salix wolfii*)	intolerant	7.5-10
Russet buffaloberry (*Shepherida canadensis*)	moderately tolerant	7.5-11.5
Mountain snowberry (*Symphoricarpos oreophilus*)	intermediate	5.5-10
Grouse whortleberry (*Vaccinium scoparium*)	tolerant	8.5-11.5

1/ Species list compiled from Barth (1970), Costello (1954), Graybeal (1973), Moir (1969) and Wirsing (1973).

2/ Shade tolerance ratings: intolerant--grows best in full sunlight; slightly tolerant--prefers open sites, but will grow under light shade; intermediate--grows well in either partial shade or in the open; moderately tolerant--grows in partial shade; tolerant--grows best in full shade. Ratings were based on limited published data (U.S. Forest Service, 1937), personal observation and communication with Pat O. Currie, Wayne L. Regelin, Olof C. Wallmo and Charles Feddema of the Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.

3/ Elevational distributions taken from Harrington (1954).

REPORT ON THE CURRENT STATUS OF THE UPPER COLORADO ENVIRONMENTAL PLANT CENTER

Glenn F. Carnahan
Manager
Upper Colorado Environmental Plant Center
Soil Conservation Service
Meeker, Colorado

The Plant Materials Center is one of the 21 centers located in the United States including one in Hawaii and one in Alaska. Some of these centers have been in existence since the mid 1930's. The past record of these centers, particularly in the development of forage and erosion control plants, has been excellent. Many varieties have been released for public use, but it is equally important that centers have been able to maintain a supply of foundation quality seed that is available to growers for using to plant commercial seed production fields.

A considerable amount of research has been done on many native species to overcome seed germination problems, but very little has been done toward the release of superior varieties and seed or plant material production. This center is being established to help solve some of the revegetation problems that now exist and those that are anticipated with the Upper Colorado Region. It is also in a location where high altitude vegetation problems can be studied without having to travel any great distance. Other problems will be considered such as improving low precipitation rangelands, highway and roadside seeding, wildlife food plants, etc.

Many people were involved in the effort to establish a new center in the Upper Colorado Region. Two Soil Conservation Districts, Douglas Creek and White River SCD's, were particularly interested. It was partially because of their interest and efforts that the decision was made to locate the center near Meeker. Other important factors were high elevation, soils, high quality water in sufficient quantity and a landowner who was ready to sell the desired parcel of land.

The two Soil Conservation Districts agreed to accept the responsibility of owning and operating the center. All funds for establishing and operating the center are received by the SCD's as grants. The U. S. Soil Conservation Service agreed to act as grantor agency and handle all grants from other federal agencies. The Districts handle all grants from state governmental and private sources. The following agencies or organizations have contributed funds to the Center: 1) U. S. Soil Conservation; 2) U. S. Fish & Wildlife Service; 3) U. S. Bureau of Land Management; 4) U. S. Forest Service (SEAM);

5) Energy Research and Development Administration; 6) Environmental Protection Agency; 7) Colorado Seed Growers Association; 8) W. R. Grace & Company through Colowyo Coal Company; 9) Atlantic Richfield Company for Colony Development Operation; and 10) Shell Oil Company.

After the land was obtained, work was commenced. The following are brief descriptions of the major things that have been accomplished to date:

1. A spring located approximately two miles to the south was developed and piped to the headquarters. This was done in cooperation with the landowner who owns the land the spring is on. Good quality ground water is difficult to obtain in this area so a well was not attempted. Many ranches have used cisterns that they fill by hauling water from town or other sources. With a 3,500 gallon storage tank, this will supply enough water for domestic purposes. Canal water will have to be used for lawns and other vegetation at the headquarter's site.

2. A fence was constructed around the entire perimeter of the EPC land. The gates and canal crossing are not completed, but are scheduled for this spring. The fence was built to discourage deer from getting over or through. So far it has accomplished this with no adverse effects on the deer. It will also prevent rabbits from getting through provided they don't dig under or get through open gates.

3. The headquarter's site was selected, staked, surveyed and leveled in preparation for building to begin. The average ground slope is 3% to the north. This site was leveled with 1% slope to the north and 0.5% slope to the east.

4. Approximately 80 acres of the 189 acres the center occupies were staked, surveyed, and designed for leveling. With the field divided into several smaller ones and with the use of flat benches, it is being leveled with 2.0 to 2.5% slope to the north and 0.5% slope to the east. Direction of irrigation will be to the east. This project is about 2/3 completed. All heavy cut areas are being overcut and backfilled with topsoil to maintain uniform surface soil for testing purposes.

5. Contracts were awarded for the construction of two buildings. They are Armco metal and the structure is guaranteed for twenty years including paint. The Seed Cleaning and Storage building is 98' 8" by 40'. This will serve as temporary office and also a shop until permanent facilities can be constructed. There are a few small items left to complete on the seed building that will be done when weather permits this spring. The equipment building is 98' 8" by 30'. This will

be used only for equipment storage particularly during the winter months.

We moved in on January 13, 1976.

6. An irrigation system is being designed by the local Soil Conservation Service engineering staff. It is nearly complete. The system proposed consists of buried pipelines which will carry the water to the fields and gated pipe for distribution to a furrow system. One of the major problems is tailwater removal. This is still being worked on.

This system will also allow the use of a portable sprinkler system which can be used to help establish new seedings.

7. Telephone service to the site has been a major problem. We are on an eight-party line and it appears that this will not change until sometime in 1977 when a buried cable is scheduled to be installed. A considerable amount of time has been spent discussing the situation with people from the telephone company, but we have been unable to speed them up. They would put in a special private line for a cost of over $4,000.00. The Administrative Board decided to try the present system for a while to see how well it works. There have been a few problems with people trying to call in, but it is not as bad as we expected.

8. Electric service is 3-phase and buried lines are installed to the locations of all planned facilities. Water lines are also installed to all locations. The sewer system is completed and hook-ups are ready for the office and residence. A separate system consisting of only a sump is planned for the greenhouse. The sewer system consists of a main line and 2,000 gallon capacity septic tanks with a drain field. This was done in cooperation with the state health department. The septic tanks and drain field are located in the field immediately to the east of the headquarters.

9. A contract has been awarded for a residence that will be located at the headquarters. A basement has been completed and the contractor plans to being work on the building soon. Weather has been a major factor in delaying the work. Drifting snow partially filled the basement.

The greenhouse and lath house are scheduled to be completed in the summer of 1976. Information is being accumulated from as many sources as possible in order to get a design that will be most suitable for this climate.

10. Equipment of all types is being purchased as rapidly as possible. Much has been obtained, but much more is needed. Schedules of equipment purchases and planned purchases have been prepared and will be distributed to all committee members. A schedule for facility establishment along with the summary of expenditures will also be distributed to committee members.

11. It is planned to begin seeding test plantings on the center this spring. Seed collected during 1975 resulted in the accumulation of nearly 650 accessions of native forbs, grasses and woody plants. Some of these can be planted this spring.

Seed has also been obtained from other plant material centers and plant introduction stations. We now have well over 2,000 accessions. We plan to continue to collect and accumulate any plant material that may have a potential use in programs the center is involved in.

12. Although the grounds appear to be in a disorderly state and there are quite a few loose ends, we feel that the establishment of the center is moving as rapidly as possible.

The driveway areas were excavated and pit-run gravel installed to give a good base. It is planned to put a thin layer of crushed gravel in as soon as the base stabilizes as the ground dries, and hopefully, someday the driveways will be blacktopped.

Landscaping will be done as rapidly as possible. Plans are to use native materials as much as possible

SHRUBS FOR THE SUBALPINE ZONE OF THE WASATCH PLATEAU

A. Perry Plummer
Intermountain Forest and Range Experiment Station
USDA Forest Service
Ogden, Utah 84401

ABSTRACT

Most of the native shrubs on subalpine areas of the Wasatch Plateau have been trial planted. Wildings of some species were transplanted as early as 1913. These early trials, and more recent direct seeding and transplanting experiments, have identified a number of shrubs that have promise as ground cover and forage. Important among these are mountain snowberry (Symphoricarpos oreophilus), lanceleaf rabbitbrush (Chrysothamnus viscidiflorus lanceolatus), Rothrock big sagebrush (Artemisia tridentata rothrocki), redberry elder (Sambucus racemosa pubens microbotrys), and mountain big sagebrush (A. tridentata vaseyana). Mechanical seed harvesting appears feasible for some shrubs, but, to a large extent, hand techniques are necessary. The development of seed orchards at lower elevations appears feasible.

INTRODUCTION

Considerable testing of plants to determine their adaptation to high elevations has been done in the subalpine zone of the Wasatch Plateau in central Utah. Major parts of these trials have been devoted to herbs, but some have also dealt with shrubs. Some testing of shrubs in high mountain areas also is being done on road cuts and fills in Idaho and on mine spoils in Montana and Wyoming.

My report today primarily concerns adaptation of native shrubs to the subalpine portion of the Wasatch Plateau. Experience has shown that results are fairly representative of what is observed on other high mountain ranges. Improvement of the vegetal cover on the plateau has been an important concern. In the future, added emphasis will be placed on adaptation of shrubs to this area as well as other high-elevation mountain areas in the West.

The plateau is 70 miles long and the subalpine portion is essentially a continuous 50-mile segment, usually between 9,500 and 10,500 feet in elevation. Some higher peaks are above timberline and may be regarded as alpine. The highest point, South Tent, is 11,282 feet. The plateau is subtended below by the Canadian, Transition, and Upper Sonoran vegetal life zones. Fairly extensive plantings have been made in all lower zones, but with most emphasis on herbs. However, more attention has been given to shrubs in these lower zones than in the subalpine zone.

The top of the plateau is long, narrow, and quite flat. Its axis runs approximately north and south with riblike extensions to the east and west. Snowbanks persist summer long in some years, and temperatures may drop below freezing in July and August. Long-term climatic data (since 1913) show that a maximum air temperature of 75°F is seldom attained. The growing season seldom exceeds 80 days.

Annual precipitation is about 32 inches. Monthly distribution is markedly cyclic. Although summer precipitation is not great, high intensity summer storms for brief periods of 30 minutes and less have caused heavy runoff and erosion from depleted watersheds. These storms resulted in disastrous erosion and mud-rock flows in communities at the base of the plateau between 1880 and 1940. In recent years, the mud-rock flows have stopped and highly damaging erosion has declined substantially as a result of improved cover.

Although summer flooding from high mountains was a common occurrence over much of the West between 1880 and 1940, it was particularly acute on the Wasatch Plateau. Hence, A. W. Sampson was appointed by the Secretary of Agriculture to inaugurate studies in 1912 on this plateau to discover causes and cures for the serious erosion and summer flooding from high mountain ranges. His findings and those of his successors firmly established that the high erosion and the damage to towns by mud-rock flows from high mountains were a direct consequence of seriously reducing the vegetal cover by overgrazing. The cure was restoration of an adequate cover. This required lighter grazing, better range management, and artificial revegetation. This has been done to a great extent, and much credit is due the Forest Service, the managing agency. However, much remains to be done on the Wasatch Plateau and other high mountain areas to appropriately stabilize them. The presence of old and new mining spoils and development of new roads and recreation areas accentuate the need.

Soil parent material on the plateau is limestone, shale, and sandstone. Accordingly, soils are mostly clays, and occasionally sandy clay loams. Organic matter content of the surface soil varies from 8 to 1 percent and averages between 5 and 6 percent. The average percent nitrogen is about 0.3, with some samples having as little as 0.1 and others as much as 0.5. Soils are slightly acidic to slightly basic, ranging in pH from 5.9 to 7.5. Acidity is somewhat greater in timber patches than outside of them (Ellison, 1954).

Herbaceous communities of mixed grasses and forbs are more extensive on the Wasatch Plateau than the area dominated by trees or shrubs. The mixed herbaceous cover is regarded as climax where it dominates (Ellison, 1954). Small patches of Engelmann spruce (Picea engelmannii) and subalpine fir (Abies lasiocarpa) dot the rolling terrain. These trees form dense forests on steep northerly exposures where they are climax.

Quaking aspen (Populus tremuloides) extends into the subalpine zone from the forests in the Canadian zone below and is fairly common on southerly exposures. Limber pine (Pinus flexilis) is common on steep, rocky, southerly exposures. Shrubs occur widely over the landscape, particularly on more gravelly hillsides. Gooseberry currant (Ribes montigenum) is probably the most prominent shrub, followed by redberry elder (Sambucus racemosa pubens microbotrys), and then mountain snowberry (Symphoricarpos oreophilus). These are referred to as part of the tall-shrub complex (Ellison, 1954). Lanceleaf rabbitbrush (Chrysothamnus viscidiflorus lanceolatus), Rothrock sagebrush (Artemisia tridentata rothrocki), and mountain sagebrush (A. tridentata vaseyana) are regarded as the major components of the low-shrub complex.

RESULTS FROM PLANTING

Over the years since 1913, most of the native shrubs and a few exotics have been test planted in the subalpine zone and in the Canadian zone below. Both direct seeding and transplanting have been tried. Results are summarized in Table 1.

Much more emphasis has been devoted to learning how to establish herbaceous plants. Species and techniques for this have been pretty well worked out (Plummer et al., 1955, 1968). Much of this reported information is also applicable to the planting of shrubs.

Because of their ability to grow well on severe sites and provide nutritious forage, especially in periods when herbaceous plants are dormant, shrubs are highly important. Sampson and Weyl (1918) demonstrated the value of transplanting native shrubs from nearby areas to terraces and gullies on westerly and southerly exposures as a means of reducing erosion. Although Forsling and Dayton (1931) reported some rather low survival from a number of these shrub plantings, they noted some good success. They stated gooseberry currant established well and made a good cover in gullies, but emphasized that plantings of quaking aspen, Scouler willow (Salix scouleriana), and grayleaf willow (Salix glauca) were failures.

The shrub transplants Sampson made were wildings, which were simply parcels or edgings having a portion of a root and stem dug from mature clumps. These segments were planted in holes made with a shovel. Greenhouse-rooted cuttings of the willows were similarly planted. Plantings were in gullies and often in contour furrows made with a horse-drawn moldboard plow. On seeing these 35 years later, it was evident that gooseberry currant, redberry elder, and lanceleaf rabbitbrush were substantially expanding their area of occupation and were doing an excellent job of stabilizing the formerly severely disturbed sites on subalpine landscapes. Gooseberry currant and redberry elder had increased vegetatively to become colonies of bushes several feet in diameter. Lanceleaf rabbitbrush had spread dramatically through natural reproduction from seed. This low shrub appears to have outstanding merit for stabilization purposes on high-altitude ranges. In addition, it provides the needed cover for establishment of a variety of herbaceous plants.

More recent plantings have identified several other shrubs that show promise for providing cover on high-elevation ranges. In transplanting trials, the best ones have been mountain big sagebrush, Rothrock sagebrush, woods rose (Rosa woodsii ultramontana), and mountain snowberry. An exotic, oldman wormwood (Artemisia abrotanum), has established well from 12- to 20-inch-long stem cuttings placed in moist ground soon after the snowmelt. On several sites, established root cuttings of this sage were better than the nonrooted ones. In addition to ease of establishment, another major value of this shrub is that it provides a favorable microenvironment for establishment of herbaceous species. Small mammals show preference for the bark of oldman wormwood, and stems are eventually girdled, causing the shrubs to die. Because of this and the fact that the shrub has never been observed to produce viable seed, it has not become a sustained part of the cover.

Results have been erratic from direct seeding trials of several shrubs, but establishment of lanceleaf rabbitbrush, mountain snowberry, gooseberry currant, fringed sagebrush (Artemisia frigida), mountain sagebrush, Rothrock sagebrush, and woods rose has been highly encouraging.

An important reason for poor establishment from direct seeding of some shrubs has been the low-quality seed that was collected and used. Collections from high-elevation native stands have often had low seed fill. In addition, the seed was highly dormant. To obtain good quality seed from high-elevation sources, it will probably be necessary to develop seed orchards of the species at slightly lower elevations where there is a longer growing season and some supplementary water. On the basis of our adaptation trials, this appears a feasible approach. Seed collections from native plants in the next lower zone probably would be satisfactory for planting in the subalpine zone, but this is yet to be determined. On the basis of reciprocal transplanting trials made by Clausen et al. (1940), it appears more desirable to use seeds and transplant material from the elevational zone in which they naturally occur. However, we do know that some species have a much wider amplitude of adaptation to climatic zones than others.

Experience with spring and fall transplanting of shrubs confirms that spring is preferred to fall. Success in the fall requires a moist soil at planting time and a continuous insulating snow cover that will keep it moist. This does not occur with enough regularity to make fall transplanting a reliable method.

In contrast to transplanting, direct seeding must be done in the late fall. Wintering in the soil is required to overcome the inherent dormancy of most shrub seeds.

HARVESTING SEEDS

It is still necessary to resort to hand procedures in harvesting most seed of high-elevation shrubs. New vacuum seed harvesters can be used to advantage for obtaining seeds of rabbitbrush and sagebrush species. Ingenuity in the development of shoulder hoppers (Plummer et al., 1968) or other devices to facilitate more rapid collection appears to be the best solution to problems in harvesting seeds of shrubs that produce berry-type fruits. We are looking forward to further development of equipment that will make seed harvesting more rapid and efficient.

LITERATURE CITED

Clausen, Jens, David D. Keck, and William H. Hiesey. 1940. Experimental studies on the nature of species. Carnegie Institution of Washington, Publ. 520. Washington, D.C. 452 p.

Ellison, Lincoln. 1954. Subalpine vegetation of the Wasatch Plateau, Utah. Ecol. Monogr. 24(2):89-184.

Forsling, C. L., and William A. Dayton. 1931. Artificial reseeding on western mountain range lands. U.S. Dep. Agric. Circ. 178, 48 p.

Plummer, A. Perry, A. C. Hull, Jr., George Stewart, and Joseph H. Robertson. 1955. Seeding rangelands in Utah, Nevada, southern Idaho, and western Wyoming. U.S. Dep. Agric. Handb. 71, 73 p.

Plummer, A. Perry, Donald R. Christensen, and Stephen B. Monsen. 1968. Restoring big game range in Utah. Utah Div. Fish and Game Publ. 68-3, 183 p.

Sampson, A. W., and L. H. Weyl. 1918. Range preservation and its relation to erosion control in western grazing lands. U.S. Dep. Agric. Bull. 675, 35 p.

Table 1. Ratings of adaptation attributes[1] of 20 shrubs for high-elevation mountain areas.

	Established by seed	Established by transplants	Seed production and handling	Natural spread (seed)	Natural spread (vegetative)	Growth rate	Soil stability	Adaptation to disturbance
Artemisia abrotanum (Exotic) Oldman wormwood	-	5	-	-	4	5	4	4
Artemisia frigida Fringed sagebrush	3	5	3	4	3	5	3	4
Artemisia tridentata vaseyana Mountain big sagebrush	3	5	4	5	2	5	4	5
Artemisia tridentata rothrocki Rothrock sagebrush	2	5	2	4	3	5	5	5
Berberis repens (Mahonia) Creeping barberry	3	3	3	-	3	3	5	5
Ceratoides lanata (Eurotia) Winterfat	3	3	3	4	2	4	3	4
Chrysothamnus nauseosus salicifolius Mountain rubber rabbitbrush	4	4	4	5	3	5	4	5
Chrysothamnus viscidiflorus lanceolatus Lanceleaf rabbitbrush	4	4	5	5	4	3	3	3
Holodiscus discolor Rock spirea	3	3	3	4	3	4	4	4
Lonicera involucrata Bearberry honeysuckle	1	4	2	2	3	3	3	2
Populus tremuloides Quaking aspen	0	2	1	0	4	2	4	5

Table 1. (Cont.)

	Established by seed	Established by transplants	Seed production and handling	Natural spread (seed)	Natural spread (vegetative)	Growth rate	Soil stability	Adaptation to disturbance
Potentilla fruticosa Bush cinquefoil	2	5	3	3	3	3	3	3
Prunus virginiana melanocarpa Black common chokecherry	2	4	4	3	5	4	5	5
Ribes cereum inebrians Squaw currant	2	3	2	2	3	3	4	3
Ribes montigenum Gooseberry currant	4	5	3	3	4	3	4	4
Rosa woodsii ultramontana Woods rose	4	4	4	3	5	3	4	5
Rubus idaeus sachalinensis (*strigosus*) American red raspberry	-	5	2	-	3	4	4	4
Salix scouleriana Scouler willow	-	4	-	-	3	3	4	4
Sambucus racemosa pubens microbotrys Redberry elder	1	3	5	1	5	5	5	3
Symphoricarpos oreophilus Mountain snowberry	4	5	3	4	5	3	5	5

[1]Key to adaptation ratings: 0 = none; 1 = very poor; 2 = poor; 3 = medium; 4 = good; 5 = very good.

COLLECTING AND CLEANING OF WILDFLOWER SEED

Gene P. Milstein
and
Dee Milstein
Applewood Seed Company
Lakewood, Colorado

Perhaps one of the most practical approaches to the reseeding of disturbed land with wildflowers is to collect the seed from the site the previous season. Certainly this approach would bring more satisfactory results and serve to keep costs down as well. We have had considerable experience in collecting, cleaning and storing the seeds of wildflowers and assure you that except for cleaning--which is unnecessary unless the seed is to be sold--that the methods involved are simple, straightforward and most economical.

The first step is to observe the flowers when they are blooming in order to make positive identification of the plants at a later date after the flowers have disappeared. The seeds of most wildflowers mature approximately 6 to 8 weeks after the flowers have fully opened; however, this timing is affected by elevation, temperature and precipitation, with ripening and dispersement occurring in a shorter period of time at higher elevations, higher temperatures and less precipitation.

It is essential to observe the plants at frequent intervals after the flowers begin to fade; every 1 to 2 weeks is usually sufficient. Note carefully the formation of the seed, that is, whether in a pod (i.e., columbine, penstemon, primrose), seed head (most composites) or fruit (rose hips, holly grape, cactus). The ideal time to collect seed produced in a pod or on a seed head is at the time the seed begins to disperse naturally. This will not only assure maturity of the seed, but will make cleaning a much easier task. Seed pods collected <u>before</u> they open will not open even after a period of dry storage. On the other hand, if the pods are collected after they have opened, the seed will disperse readily and cleaning will be unnecessary. Seed heads may be collected after the seed has changed color (usually from green to brown or black) and the majority of the seed disperses easily, but not so easily that it is lost.

There is much greater flexibility in collecting seed contained in fruits as they often remain on the plant until the following spring.

Successful collecting is a matter of percentages. The seed produced by a species in a given area will mature at a different rate from plant to plant. Therefore, collecting must be so timed as to coincide with the maturation of the majority of the seed in the area; this is particularly noticeable in the case of legumes (i.e., lupine, golden banner) because their seeds, even on the same plant, mature quite sporadically. Even during the most efficient harvest, only a percentage of the available seed will be at the optimum stage for collecting; for this reason, it is very important to collect a representative sampling from the area before deciding that the time is right for collecting. In the case of seed pods, most of the pods should be open; seed heads should have begun to release their seeds. Fruits may be collected safely after they have reached maximum color and have begun to dry. We have found with a minimum of experience and careful observation, one can easily determine the appropriate harvesting time for wildflower seeds.

Any number of containers are suitable for collecting, including plastic or paper bags, boxes or metal cans. The pods or seed heads can usually be broken off easily by hand without disturbing root systems. When stems are particularly tough, it is helpful to use a pocket knife. In any event, wearing gloves is advisable in order to prevent allergic reactions which are common in the case of pasque flower and certain other species.

Select an area where growth of the species is abundant and you will be amazed at how quickly large quantities can be collected. This is not only because the seeds of most wildflowers are very small (100,000-200,000 seeds per ounce), but also because many species native to the mountains and the plains produce large numbers of seed.

It is helpful to note and record the exposure and terrain if markedly different conditions exist within a given area. Also, it is ideal to collect species that bloom at different times of the year in order to enhance the overall restoration of the disturbed area.

Prompt drying of the material is extremely important. Never assume the material is dry even though it may look and feel dry. Drying is best accomplished by spreading out the plant material as thinly as possible in a well-ventilated, protected area within several hours after collecting. Failure to do so may result in a harmful build-up of heat and moisture as well as the formation of mold, all of which have a detrimental effect on seed viability. In most cases 1 to 2 weeks is required for thorough drying; during this time, turn the material on a daily basis to insure even and complete drying.

Cleaning is time-consuming and represents a substantial part of the cost of most commercially available seed. However, cleaning is usually unnecessary in situations where the seed is not going to be offered for sale. In fact, reseeding with uncleaned seed has advantages in terms of handling and provides a natural mulch which will help to retain moisture and hold the seed in place until it germinates.

If closed seed pods have been collected, however, they must be crushed before planting or germination time will be substantially delayed. This may be accomplished with a mechanical vehicle or, if the quantity is small, with the feet. Removing seeds from fruits also will greatly reduce germination time. Dried fruits may be crushed in the above manner; fresh fruits may be pressed through a screen and the pulp removed by washing or flotation.

Store the seed in a cool, dry atmosphere in containers that will afford protection from rodents.

Sowing of wildflower seed is likely to be most successful in areas where intermittent ground cover has been established in order to protect the small seeds from being washed or blown away. Wildflower seeds sown on completely bare ground have little chance for survival. Wildflowers are usually not sown with grass seeds because they easily may get buried too deeply in a heavy mulch or planted too deeply in a drilling operation.

In summary, collecting wildflower seed the previous season from the site or area that will require restoration is suggested as a practical and economical approach to the treatment of disturbed land. Cleaning of the seed is usually unnecessary if collecting is properly timed, and may even have a beneficial effect.

Listed in Table 1 are a number of species of wildflowers, with information as to germination time, ideal temperatures and special requirements for germination. This material appears in Water, Light & Love, A guide to Growing Plants from Seeds, Dee and Gene Milstein, Applewood Seed Co., Lakewood, Colorado, 1976.

CHARTS

Kind of Seed

Species included in the charts are primarily those with which the authors have had personal experience. Others have been included because of general interest and the availability of reliable information.

Type

H - hardy	P - perennial
HH - half-hardy	B - biennial
T - tender	A - annual

+ - Usually grown as an annual

Tender annuals, biennials and perennials are unable to withstand cold and are injured or killed by a light frost. Half-hardy annuals may endure a few degrees of frost but are killed at lower temperatures; half-hardy biennials and perennials are injured by severely cold winters, such as those in northern United States, and require special protection (e.g., mulching) during part of the year. Hardy annuals are capable of resisting frost or light freezing; hardy biennials and perennials can withstand extremely cold temperatures.

Germination Time

Indoor and outdoor germination times are approximate and based on the fulfillment of any special requirements noted in the charts.

Indoor Temperature

Temperatures indicate the ideal range for indoor germination. An asterisk (*) means that there is no reliable information available on indoor temperature requirements, and that the species probably responds best to being sown outdoors where temperatures fluctuate widely from night to day.

TEMPERATURE CONVERSION TABLE

$50^oF = 10^oC$	$65^oF = 18^oC$	$80^oF = 27^oC$
$55^oF = 13^oC$	$70^oF = 21^oC$	$85^oF = 30^oC$
$60^oF = 16^oC$	$75^oF = 24^oC$	$90^oF = 32^oC$

Special Requirements

The term light indicates that the presence of light either promotes or is a requirement for germination. Indoors, these seeds should not be covered with the medium; they may be germinated either in a well-lighted room or under fluorescent lamps. Outdoors, seeds requiring light may be protected by a very thin covering. The term dark means the absence of light either promotes or is a requirement for germination; these seeds may either be covered with the medium or germinated in a dark room.

Directions for moist-chilling are given in chapter 9. An alternative to moist-chilling is to sow seeds outdoors in the late fall or early spring, depending on climate and the specific needs of the species. Seeds requiring only one month of moist-chilling may be germinated in a greenhouse, provided nighttime temperatures are in the range of 45° to 50°F (7° to 10°C).

GERMINATION TIME
(Number of days)

Kind of Seed	Type	Indoor	Outdoor	Indoor Temp.	Special Requirements
ASPEN DAISY (FLEABANE) *Erigeron speciosus*	HP	10-15	15-20	60-75°F	
BITTER-ROOT *Lewisia rediviva*	HP	20-25	20-35	60-70°F	Moist-chill 2-3 months.
BLACK-EYED SUSAN *Rudbeckia hirta*	HB	10-15	15-20	60-70°F	
BLEEDING HEART *Dicentra eximia* *D. spectabilis*	HP	25-30	30-40	60-70°F	Moist-chill 2-3 months. D. eximia prefers acid soil, pH 5.0 to 6.0
BLOODROOT *Sanguinaria canadensis*	HP	*	20-30	*	Moist-chill 2-3 months.
BUTTER-AND-EGGS *Linaria vulgaris*	HP	15-20	20-30	60-75°F	
CACTUS: PRICKLY-PEAR *Opuntia* spp. PINCUSHION *Mammillaria* spp. CHOLLA (BUSH CACTUS) *Cylindropuntia* spp.	HP	20-30	40-60	60-75°F	
CARDINAL FLOWER *Lobelia cardinalis* *L. siphilitica*	HP	15-20	20-30	60-70°F	Light

GERMINATION TIME
(Number of days)

Kind of Seed	Type	Indoor	Outdoor	Indoor Temp.	Special Requirements
CLEMATIS					
Clematis hirsutissima					Moist-chill *C. hirsutissima* for
C. ligusticifolia					1-2 months; others listed require
C. orientalis	HP	20-30	30-40	60-70°F	no special treatment.
COLUMBINE					
Aguilegia alpina					Light. Soak in water 12-24 hours
A. caerulea					before sowing. Some species not
A. vulgaris	HP	20-25	30-40	60-70°F	listed may require moist-chilling.
DELPHINIUM, WILD					
Delphinium geyeri					
D. nelsonii	HP	*	30-40	*	Moist-chill 2-3 months.
DUTCHMAN'S BREECHES					
Dicentra culcullaria	HP	25-30	30-40	60-70°F	Moist-chill 2-3 months.
EDELWEISS					
Leontopodium alpinum	HP	10-14	15-20	60-70°F	Light
EVERGREEN TREES:					
BLUE SPRUCE					
Picea pungens	HP	10-15	20-30	65-75°F	
BRISTLE-CONE PINE					
Pinus aristata	HP	10-15	20-30	65-75°F	
PINYON PINE					
Pinus edulis	HP	15-20	20-30	65-75°F	Light
PONDEROSA PINE					
Pinus ponderosa	HP	10-15	20-30	65-75°F	Light

GERMINATION TIME
(Number of days)

Kind of Seed	Type	Indoor	Outdoor	Indoor Temp.	Special Requirements
FIREWEED					
Epilobium angustifolium	HP	10-15	15-30	60-70°F	
FLAX					
Linum lewisii					
L. perenne	HP	10-15	15-30	60-70°F	
FORGET-ME-NOT					
Myosotis palustris semperflorens					
M. alpestris	HP	5-10	10-15	65-75°F	
GAILLARDIA					
Gaillardia aristata	HP	15-20	20-30	60-70°F	
GAYFEATHER (BLAZING STAR)					
Liatris punctata					
L. spicata	HP	15-20	20-30	60-70°F	
GENTIAN					
Gentiana acaulis		20-25	25-30		
G. calycosa		10-15	15-20		
G. thermalis	HP	20-25	25-30	60-65°F	Moist-chill 1-2 months.
GERANIUM, WILD					
Geranium fremontii					Overcome sporadic indoor germin-
G. maculatum					ation by light scarification with
G. sanguineum	HP	10-30	20-30	60-70°F	a file or #2 sandpaper.

Kind of Seed	Type	GERMINATION TIME (Number of days) Indoor	Outdoor	Indoor Temp.	Special Requirements
GILIA (FAIRY TRUMPET) *Gilia aggregata* *G. rubra*	HB	10-15	15-30	60-70°F	
HAREBELL *Campanula carpatica* *C. rotundifolia*	HP	10-15	20-30	65-75°F	Light
HEATHER *Calluna vulgaris*	HP	25-30	30-40	60-70°F	Light. Prefers acid soil, pH 5.5 to 6.5.
IRIS, WILD BLUE *Iris missouriensis*	HP	20-30	30-40	60-70°F	Scarify with a file, #2 sandpaper, or by snipping off pointed end of seed with nail clippers; then moist-chill 1-2 months. Or sow outdoors in the fall without scarifying.
INDIAN PAINTBRUSH *Castilleja chromosa* *C. indivisa* *C. integra* *C. lineariaefolia* *C. miniata*	HP	15-20	20-35	60-70°F	*C. chromosa* and *C. miniata* require moist-chilling for 1-3 months. *Castilleja* spp. are semi-parasitic on roots of other plants (e.g., grasses, sage) and must be transplanted outdoors after 4-6 weeks of growth. Sow seeds in small pots and transplant seedlings en masse to permanent location as roots are easily damaged.

GERMINATION TIME
(Number of days)

Kind of Seed	Type	Indoor	Outdoor	Indoor Temp.	Special Requirements
JACK-IN-THE-PULPIT Arisaema triphyllum	HP	*	30-40	*	Moist-chill 2-3 months. Prefers acid soil, pH 5.5 - 6.5.
JOHNNY JUMP-UP Viola cornuta	HP	5-10	10-15	65-75°F	
KINNIKINNIK (BEAR-BERRY) Arctostaphylos Uva-ursi	HP	15-30	20-40	75-80°F	Soak seeds 2-5 hours in conc. sulfuric acid; either sow outdoors in early summer for germination the following spring or stratify at 77°F (25°C) for 60-120 days, followed by moist-chilling for 60-90 days. Another technique is to snip off pointed end of seeds and stratify as above (germ. times will be longer).
LITTLE RED ELEPHANT Pedicularis groenlandica	HP	15-20	20-30	60-65°F	Moist-chill 2-3 months.
LUPINE Lupinus argenteus L. texensis (bluebonnet)	HP HA	10-20	15-30	65-75°F	Pour boiling water over seeds and soak 12-24 hours before sowing.

Kind of Seed	Type	GERMINATION TIME (Time of days) Indoor	Outdoor	Indoor Temp.	Special Requirements
MAIDEN PINKS					
Dianthus deltoides	HP	5-10	10-15	65-75°F	Light
MARIPOSA LILY					
Calochortus nuttallii					
C. catalinae	HP	*	25-30	*	Moist-chill 1 month.
MAP-APPLE					
Podophyllum peltatum	HP	*	30-40	*	Moist-chill 2-3 months.
MONKEYFLOWER					
Mimulus lewisii	HP				
M. longiflorus	HHP				
M. moschatus	HP				
M. tigrinus	HHP	5-10	10-15	65-75°F	
MONK'S HOOD					
Aconitum napellus	HP	20-30	30-40	60-70°F	Moist-chill 1 month.
OX-EYE DAISY					
Chrysanthemum leucanthemum	HP	10-15	15-20	60-75°F	
PASQUE FLOWER					
Anemone pulsatilla	HP	15-25	30-40	55-65°F	Germination sporadic.

GERMINATION TIME
(Time of days)

Kind of Seed	Type	Indoor	Outdoor	Indoor Temp.	Special Requirements
PENSTEMON					
Penstemon alpinus					
P. barbatus					Light. *P. alpinus*, *P. palmeri*,
P. heterophyllus					*P. unilateralis* may require
P. palmeri					1-3 months moist-chilling.
P. unilateralis	HP	15-20	20-35	60-70^{o}F	
POPPY, WILD					
Eschscholzia californica	HHP	10-15	15-30	60-65^{o}F	Germination sporadic.
PRIMROSE					
Oenothera biennis	HB				
O. fructicosa youngii	HP				
O. hookeri	HB				
O. lamarckiana	HB	10-15	15-20	65-75^{o}F	
RHODODENDRON, WILD					
Thododendron ferrugineum	HP	20-30	30-40	60-70^{o}F	Moist-chill 1 month. Prefers acid soil, pH 5.5 to 6.5.
ROSE OF SHARON					
Hypericum calycinum	HP	15-20	20-30	60-70^{o}F	Moist-chill 1 month.
ROSE, WILD					
Rosa woodsii	HP	*	30-40	*	Light. Moist-chill 1 month.
SAXIFRAGE, TUFTED					
Saxifraga caespitosa	HP	15-20	20-30	60-70^{o}F	

GERMINATION TIME
(Number of days)

Kind of seed	Type	Indoor	Outdoor	Indoor Temp.	Special Requirements
SHOOTING STAR					
Dodecatheon clevelandii					
D. meadia					Some species not listed may
D. pulchellum	HP	20-30	30-40	60-70°F	require moist-chilling.
SUNFLOWER					
Helianthus annuus	HA				
H. petiolaris	HA				Requires cool temperatures
H. pumilus	HP	10-15	15-20	50-60°F	for germination.
YUCCA					
Yucca baccata					Light. *Y. glauca* and *Y.*
Y. filamentosa					*filamentosa* require 1 month
Y. glauca	HP	15-30	30-40	60-70°F	moist-chilling.

ACCLIMATION OF TREES AND SHRUBS TO HIGH ALTITUDES

B. T. Swanson
Department of Hortculture
Colorado State University
Fort Collins, Colorado

Research to study the acclimation of trees, shrubs, and groundcovers was started in June of 1975 in Pitkin County of Colorado. Seven sites, described as follows, were planted between June 15th and July 10th, 1975:

Site No.	Elevation	Exposure	Slope	Location
1	7,885'	West	70%	McClain Flats Road
2	8,000' approx	South	50%	County Landfill
3	7,722'	South	70%	Brush Creek Rd.
4	9,150'	North	25.5%	Snowmass Mtn.
5	9,310'	South	22.5%	Snowmass Mtn.
6	10,440'	North	34%	Snowmass Mtn.
7	10,430'	Southeast	10%	Snowmass Mtn.

Complete climatological data is being collected at sites 4 through 7 via a pyronometer, anemometer, soil and air max-min thermometer, rain gauge, avalance can, and snow stakes.

The total list of plant material planted is as listed in Table 1. Not all species were planted at all seven sites, however, sites 4 through 7 received identical plantings. Data on survival, growth, abscission and percent cover were taken in September 1975. This is considered very preliminary data as we have no indication of winter survival at this time.

Half of site 1 was the original soil as exposed when the road site cut was made. The other half was capped with 4-6 in. of a mixture of top soil and sewage sludge. The plantings in this site were watered at the time of planting and approximately weekly thereafter. All other sites were watered only at the time of planting.

Percent survival of each species at all sites is as indicated in Table 1. Drought conditions immediately after planting accounted for considerable injury at sites 4 and 5. Also, sheep damage occurred at site 5. By mid August, cold acclimation was becoming apparent in some species. Cotoneaster and Foresteria displayed good fall color by mid August. Other species, such as maple and green ash, did not acclimate but were not injured by the early frost; whereas, the dogwood and Euonymus showed some injury at this time.

Tanecetum vulgare is one species that indicated good potential for high altitude plantings. It is easily propagated by cuttings and easily planted as rooting cuttings or from its below-ground elongated rhizomes. Clematis orientalis is another good prospect for fast cover. Although it is grown readily from seed, it is difficult to sow evenly.

Until additional climatological data are collected and plant data are obtained following at least one winter, no further conclusions can be drawn.

Table 1. Total list of species planted at the Pitkin County research sites.

	Percent Survival							
	Site 1							
Species	Bare	Capped	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7
Acer saccharimum 'Blair'					100	100	100	100
Ajuga genevensis	67	36						
Artemesia abrotanum	N/A	N/A	100		93	100	93	100
Artemesia schmidtiana	100	100	44					
Bistortum distortioies	100	85						
Caryopteris incana					47	47	100	87
Chrysothamnus graveolens	100	89	100					
Clematis orientalis	93	67	30	24.5	0	87	100	87
Clematis orientalis	79	88						
Cornus stolonifera 'Coloradensis'					73	80	100	100
Cotoneaster pekinensis					73	100	100	100
Elaegnus angustifolia					100	100	100	100
Euonymus fortunei 'Coloratus'					73	87	100	100
Fallugia paridoxia	78	67	78		100	100	100	93
Foresteria neomexicana	100	100	100		100	100	100	100
Fraxinus pensylvanica 'Lanceolata'					53	80	93	100
Juniperus chinensis 'Broadmoor'					53	100	100	100
Juniperus chinensis 'Pfitzeriana'					93	100	100	100
Juniperus chinensis 'Old Gold'					100	67	100	100
Juniperus horizontalis 'Andorra'					13	66	100	100
Juniperus horizontalis 'Wiltoni'					43	73	100	100
Juniperus sabina 'Tamariscifolia'					93	100	100	100
Lugustrum sp. 'Golden Vickary'					80	80	100	100
Lysimachia nummularia	96	82						
Parthenocissus quinque-folia 'Englemann'	78	89	100					
Populus alba 'Bolleana'					40	20	93	100
Rosa foetida 'Persiana'	100	100						

Table 1. (Continued)

Species	Percent Survival: Site 1 Bare	Site 1 Capped	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7
Salix alba					47	33	93	93
Sambucus canadensis 'Auria'					33	40	80	47
Sedum acre minus	97	84						
Sedum album	79	34						
Sedum hybridum	92	74						
Symphoricarpos x chenaultii 'Hancock'	100	100	100					
Syringa chinensis					100	100	100	100
Tanecetum vulgare (R.C.)	100	93	48	8.6	47	100	73	67
Tanecetum vulgare (rhizome)	78	89						
Taxus cuspidata					87	93	100	100
Teucrium canadensis	89	70			60	40	90	90
Vinca major	N/A	N/A	56		100	100	93	100
Vinca minor	56	85	7					

REHABILITATION OF ALPINE DISTURBANCES: BEARTOOTH PLATEAU, MONTANA

Ray W. Brown
Robert S. Johnston
Bland Z. Richardson
and
Eugene E. Farmer
USDA Forest Service
Forestry Sciences Laboratory
Intermountain Forest and Range Experiment Station
Ogden, Utah

INTRODUCTION

Mineral exploration, mining, pipeline construction and recreational activities are accelerating on alpine ecosystems in the western U.S. These ecosystems are threatened with severe disruption, and in some areas, esthetic, wildlife habitat, and watershed values have already been seriously damaged. The fact that alpine tundra constitutes a relatively small proportion of the total land area in the West is in no way proportional to its importance or to the impacts that disturbance causes. Alpine ecosystems are of vital importance as metropolitan and agricultural watersheds, providing nearly year-round snow accumulation and water storage areas. These areas contain economically valuable mineral resources, and in many areas, their year-round recreational opportunities are increasingly in demand. Of particular concern is the potential damage that these activities will cause to the unique ecosystems of alpine areas. Our lack of knowledge concerning suitable rehabilitation techniques for alpine disturbances, together with the extremely short growing seasons, cool summer temperatures, high radiation loads, and other environmental conditions characteristic of alpine areas dictate that research on this problem be expanded.

The alpine zone is traditionally described as that life zone occurring above treeline in mountainous terrain, but which is not permanently covered with snow (Billings 1974a, 1974b). The boundary between alpine and forest is seldom sharp, and often is characterized by alternating patches or fingers of trees and herbaceous plants. In the classical definition of Love (1970), the traditional subalpine zone would be included as part of the alpine belt. In order to avoid semantic misunderstandings, we consider the alpine zone in this paper to extend from the forest-tundra ecotonal transition zone, including islands of krummholz trees and fingers of herbaceous alpine plants, up through the true tundra to the upper limits of vegetation.

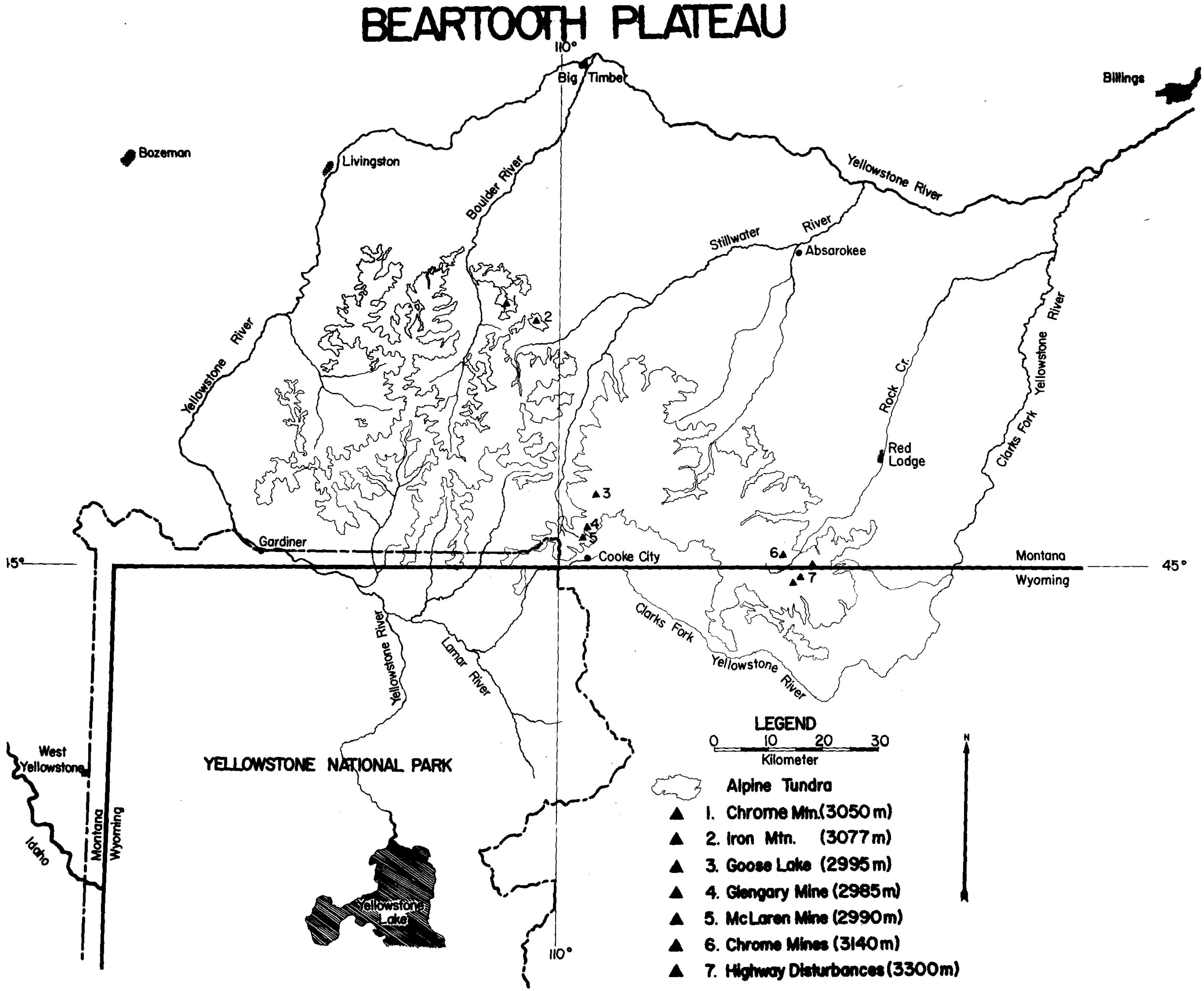
The alpine zone is typically composed of herbaceous vegetation, which in North America, includes sedges, grasses, forbs, and a few shrubs. Alpine plants usually have a dwarf-like appearance relative to herbaceous plants in other life-zones, and typically are perennial angiosperms. The alpine zone is generally described as "flora-poor," usually comprising a total flora of fewer than 300 species in North America. In many alpine areas of the Rocky Mountain west, such as on the Beartooth Plateau, fewer than 200 vascular species are known. The special physiological adaptations of alpine plants, and the role of natural selection on their morphological, physiological, reproductive and ecological characteristics have been discussed in great detail by Billings (1974a, 1974b).

The rigorous alpine environment is unique (Billings, 1974a, 1974b, 1973; Billings and Mooney 1968; Thilenius 1975), and has many characteristics that have particular importance to rehabilitation. The qualities of fragility and harshness often attributed to these environments stem primarily from the delicate appearance of the dwarf-life vegetative life-form, the visible disruptiveness caused by disturbance, the relatively long periods of time required for vegetative reestablishment, and the obvious discomfort we experience from wind, low temperatures, and high ultra-violet radiation. However, there is no evidence that the alpine is harsh to organisms that have evolved adaptations in that environment. In the absence of man, there is no evidence that alpine is fragile. But once disturbed, its rehabilitation becomes a challenge of some magnitude because of such factors as the short cool growing season, high evaporation rates, sterile rocky and shallow soils, and from the use of techniques not suited for these environments. This unique environment, coupled with the necessary adaptive features of the vegetation, must be reflected in a viable rehabilitation program for alpine disturbances.

The research reported here was conducted on the Beartooth Plateau, an alpine environment with a long history and a broad spectrum of disturbance. Hopefully, these results will contribute to our recently, yet slowly, growing knowledge of alpine rehabilitation techniques (Berg et al. 1974; Brown and Johnston 1976; Johnston et al. 1975; Marr 1974; Willard and Marr 1970, 1971).

THE BEARTOOTH PLATEAU

The Beartooth Plateau (Figure 1) in southern Montana is an uplifted Pre-Cambrian granitic block from which extensive sedimentary materials have been eroded (Bevan 1923, Loverling 1929). Basalt and acid porphyry intrusions and some limestone


BEARTOOTH PLATEAU
110°
Big Timber
Billings
Bozeman
Livingston
Boulder River
Yellowstone River
Stillwater River
Absarokee
Yellowstone River
Rock Cr.
Red Lodge
Clarks Fork Yellowstone River
2
3
4
5
6
7
Gardiner
Cooke City
45°
45°
Montana
Wyoming
Yellowstone River
Lamar River
Clarks Fork Yellowstone River
West Yellowstone
Idaho
Montana
Wyoming
YELLOWSTONE NATIONAL PARK
Yellowstone Lake
110°
LEGEND
0 10 20 30
Kilometer
N
Alpine Tundra
1. Chrome Mtn. (3050 m)
2. Iron Mtn. (3077 m)
3. Goose Lake (2995 m)
4. Glengary Mine (2985 m)
5. McLaren Mine (2990 m)
6. Chrome Mines (3140 m)
7. Highway Disturbances (3300 m)

outcrops are evident. Most of the highly mineralized zones lie on the flanks of the main Beartooth uplift, as exemplified by the Stillwater Mineral Complex on the north (Sullivan and Workentine 1964), and the Cooke City Mining District on the south (Loverling 1929). These two areas have a long history of mining activity and mineral exploration, dating back to the 1880's.

The environment of the Beartooth Plateau is similar to that of other North American alpine areas (Johnson and Billings 1962, Thilenius 1975). The soils are typically shallow and weakly developed, and are coarse textured and rocky in dry areas (Nimlos et al., 1965). The dominant climatic features include short growing seasons of 60-70 days at higher elevations with cool summer temperatures and relatively high solar radiation loads (Johnston et al., 1975). Annual precipitation is estimated to range between 45 and 60 inches (1140 and 1525 mm), most of which occurs as snow during the winter months (September to June). However, annual precipitation is quite variable between specific sites. The major plant communities in alpine areas have been described by Johnson and Billings (1962).

The Cooke City ore body appears to be a highly mineralized hydrothermal pyritized-copper deposit with primary values in gold, silver, and copper (Loverling, 1929). Past mining consisted of both shallow open pit and underground hard rock operations with numerous small mines and exploration sites of varying vintage and extent throughtout the area. The McLaren Mine (Figure 1) was abandoned in the early 1950's, and the last active operating mine, the Glengary, was closed in 1967 when the mill site was destroyed by an avalanche. However, active mineral exploration continues throughout the area.

The Stillwater Mineral Complex consists of a belt of igneous rock oriented in a southeast to northwest direction along the northern face of the Beartooth Mountains (Sullivan and Workentine, 1964). The olivene and pyroxene constituents of this multi-layered igneous belt were originally mined for chromite ore, beginning about the turn of the century and continuing until the 1940's. Since then, mineral exploration activities on alpine tundra have unearthed large reserves of platinum, palladium, nickel, and iron, in addition to chromite and some gold. During the last few years, extensive exploration has accelerated rapidly, and active mining may once again become a reality on this portion of the Beartooth Plateau.

At present, mining related disturbances of alpine tundra on the Beartooth Mountains include road construction, drilling sites, exploration holes, trenches, abandoned open-pit and hard-rock mines, and associated mining camps. In addition, extensive disturbance has resulted from the construction of the Beartooth Highway between Cooke City and Red Lodge (Figure 1).

abandoned mineral exploration sites in weakly acid soils with a pH of about 5.5 to 6.5. The McLaren Mine provides a contrasting study site which is older and more severely disturbed. Spoil materials are a very heterogeneous mixture of surface soils and bedrock with substantial amounts of pyrite. Soil pH on portions of the mine range between 1.8 and 3.5.

Research results so far indicate that mixtures of native species are more successful than mixtures of introduced species, that fertilizer applications are essential to plant establishment, and that additions of organic matter and/or topsoil enhance the rate of stand establishment. The Iron Mountain plots reveal these results particularly well. After one growing season (in September 1973) seed mixtures of introduced grasses had higher production levels, were taller, and generally appeared more vigorous than native grass mixtures. However, after the second growing season (September 1974), the native species began to show signs of rapid development in terms of cover and productivity, although the introduced species were still more productive and vigorous. By the end of the third growing season (September 1975), the production, density, and general vigor of the two groups were very similar. There is some evidence (based on a comparison of clipping data from the three growing seasons) that productivity of the introduced species is beginning to decline, and overall vigor is now not as impressive as that of the native species. There has been some invasion by natives into the introduced species plots, but the reverse has not been noted.

The role of fertilizer applications at the time of seeding is well established on research plots at both Iron Mountain and the McLaren Mine. A single application of a 15-40-5 granular fertilizer at the equivalent rate of about 100 lbs. N per acre (111 kg per ha), raked into the soil, has maintained a level of productivity about 100 times greater over a 3-year period than that on unfertilized plots. Unfertilized plots have shown little or no plant development after 3 years, even on those receiving heavy applications of organic matter. On the McLaren Mine, the fertilized plots supported much higher plant densities (about 3 times greater) after one growing season on both topsoil and raw spoil plots. Root penetration, plant height, and general vigor were all much higher due to fertilization (Brown and Johnston, 1976).

Organic matter incorporated into the surface soil, together with fertilizer, greatly enhances stand establishment. It apparently increases the soil water holding capacity, improves nutrient availability and aeration, and surface applications reduce evaporation and extreme surface temperatures. On the Iron Mountain plots, peat moss was applied at the rate of 2000 lbs per acre (2240 kg per ha), and was covered with a

This includes road cuts and fills, and many associated gravel pits. Also, in recent years the increased use of off-road vehicles and other recreational uses have substantially broadened the problems of disturbance on alpine tundra areas.

REHABILITATION RESEARCH PROGRAM

The current research program in the rehabilitation of alpine disturbances was begun in 1972, and has since been incorporated into the SEAM (Surface Environment and Mining) Program of the USDA Forest Service. Since then, the research program has grown to include the following activities:

1. Revegetation research on disturbed sites
    a. seeding
    b. species trials
    c. transplanting
2. Plant succession on disturbed sites
3. Physiology of plants on disturbed sites
4. Water quality research
    a. surface water quality
    b. soil water chemistry
    c. impact of roads on storm regimen and water quality
5. Microenvironmental characteristics of alpine disturbance
6. Snow accumulation and melt related to micro- and macro-surface configurations of mine surfaces.

Revegetation Research

Our revegetation research program on the Beartooth Plateau can be divided into three different categories: 1) seeding methods and amendments, 2) individual species trials, and 3) the use of transplants as a revegetation technique.

The seeding methods and amendments research was started in the fall of 1972 on Iron Mountain, and has since been expanded to include the McLaren Mine. Each year a total of 88 seeded plots are intensively monitored and assessed to determine the effects of various species mixtures, fertilizer application, the role of organic matter amendments, and the effect of topsoil applications on the development of a plant cover. The research on Iron Mountain is being conducted on single layer of jute netting. This treatment, when combined with fertilizer, appears to hasten early plant development and improves general growing conditions during dry periods of the growing season. Bioassay research in the greenhouse tends to confirm these conclusions. Applications of steer manure at the rate of 4000 lbs per acre (4480 kg per ha), combined with fertilizer, substantially increased plant productivity, height growth, root development, and general vigor in acid spoils from the McLaren Mine.

Seeding of alpine disturbances should always be accomplished during the late fall (September on the Beartooth Plateau). Spring seedings would be difficult since accessibility is poor until after snowmelt in late July. By then drying of the soil surface has begun, and the requirements of native species could not be met for current season germination. Fall seeding, however, combined with fertilizer and organic matter or mulch applications, assures that water will be available during snowmelt the following spring, and that soil conditions will be more favorable for using planting machinery. We have used seeding rates of between 25 and 50 lbs per acre (28 to 56 kg per ha), but higher rates may be justified under special conditions. Native species are selected from populations of the most active colonizers (see Plant Succession Research, below). Seeds are then collected by hand, cleaned in the laboratory, and prepared for planting. Introduced species are purchased from reliable commercial sources, and only strains originating from the Rocky Mountain area are used. The following species have been used with varying degrees of success (listed in order of success; species names after Plummer et al., 1966).

Natives	Introduced
Tufted hairgrass	*Deschampsia caespitosa*
Meadow foxtail	*Alopecurus pratensis*
Alpine bluegrass	*Poa alpina*
Timothy	*Phleum pratense*
Alpine timothy	*Phleum alpinum*
Orchardgrass	*Dactylis glomerata*
Spike trisetum	*Trisetum spicatum*
Smooth brome (Manchar)	*Bromus inermis*
Sedge	*Carex paysonis*
Intermediate wheatgrass	*Agropyron intermedium*
Scribner wheatgrass	*Agropyron scribneri*
Kentucky bluegrass	*Poa pratensis*
Slender wheatgrass	*Agropyron trachycaulum*
Alta fescue	*Festuca arundinaceae*

Individual species trials were initiated in 1975 with the above species to determine their performance under alpine conditions. This work is being done at Iron Mountain and at

Goose Lake. The seed of each species was planted in individual rows so that general performance can be judged under conditions free of interspecific competition. Although no results are yet available, this work will be expanded in 1976 on the MaLaren Mine.

Transplanting of native species has been tested as a revegetation technique on Iron Mountain since 1972, and has been expanded each year to include the McLaren Mine and Goose Lake study sites. Native grasses and sedges, listed above, together with some forbs such as pussytoes (Antennaria lanata), lupine (Lupinus argenteus), sibbaldia (Sibbaldia procumbens), and mountain heath (Phyllodoce empertriformis) have all been used. At the present, every plant at all locations has survived, and many have grown vigorously and produced an abundance of seed since being transplanted. Usually only segments of turf that have been distrubed along road cuts, and which have been broken off and slid down the cut slope, are used. In some locations on Iron Mountain, the seed produced by the transplants has produced an abundance of young seedlings on the lee sides of the plants, and many of these have apparently become well established. On small, particularly harsh sites, where conventional seeding methods are not practical, transplanting may offer the best revegetation technique available. It has been a highly successful method primarily because of the following reasons: 1) the plants are dormant when transplanted to reduce physiological damage, and 2) the well developed root systems and root crown portions are not as susceptible to desiccation and frost heaving as are young emerging seedlings.

On the basis of plant survival per individual planted, transplanting is the most successful revegetation technique available in the alpine, and on small areas, may be the most economical. We estimate that about one man-day is required to collect one pound (0.45 kg) of native seed in alpine environments. In addition, only about 10 to 30 percent of the seed is usually viable, and only a small proportion of these ultimately survive to the adult stage of development. Based on the results of our seeding research, about 3 years are required for seeded plants to reach adulthood and to produce seed heads. Transplants are usually capable of seed production after only one growing season.

Plant Succession Research

The plant successional patterns on alpine disturbances are being studied on all the Beartooth Plateau sites (Figure 1). This research has shown that plant colonization of alpine disturbances is highly variable on all nine different study locations. The rate of colonization and reestablishment of plant communities on alpine disturbances appears to be influenced primarily by three factors (not necessarily listed in order of importance): 1) availability of soil water, 2) soil chemistry conditions, and 3) age of the disturbance. Topography, soil structure, and other factors may also be important in some areas. Generally, recent disturbances less than 20 years old on mine sites with a soil pH above 5.5 support stands of scattered native vegetation. However, some older disturbances of about 30 years of age, on xeric sites with a pH below 3.5 show no signs of vascular plant colonization.

Of the nearly 200 known alpine vascular plant species constituting the flora of the Beartooth Plateau (Johnson and Billings, 1962), only about 10 percent are active colonizers on disturbances. Fewer than half of these can be classified as the more active universal native plant species found on virtually all disturbances of more than a few years age. These species include: tufted hairgrass, sedge, alpine bluegrass, spike trisetum, Scribner wheatgrass, and alpine timothy. It is notable that the most important colonizer species are all perennial grasses and sedges. No annual species are known colonizers on Beartooth disturbances in alpine environments. Only a few species of forbs are important invaders, and these only at specific locations, particularly on more mesic sites with pH's above 5. These include lupine, pussytoes, sibbaldia, and in a few locations alpine willowweed (*Epilobium alpinum*) and groundsel (*Senecio* spp.).

The role of plant succession is vitally important in the establishment of a plant cover on alpine disturbances. Plant colonization provides a visual display of adapted species and ecotypes from which native plant materials should be selected for rehabilitation. Care must be exercised in selecting adapted species together with combinations of soil amendments that are compatible with succession, and which in turn, accelerate its development. Particularly, more data are needed on what adapted introduced species can safely be combined with the natives in mixtures which do not, through competition, impede the ultimate development of a self-perpetuating vegetation cover.

Plant Physiology Research

Research on the photosynthetic capacity and the water relations of various plant species is being conducted under both field and laboratory conditions in an effort to quantify species adaptability on alpine disturbances. Photosynthesis rates of tufted hairgrass and sedge under field conditions on McLaren Mine spoil were compared with those of the same species growing on undisturbed tundra during the 1975 growing season. The results are inconclusive after only one growing season, but seem to indicate that photosynthesis rates of plants growing on mine spoil and undisturbed tundra are similar.

However, the results of water relations research indicates that the availability of water during the growing season on alpine disturbances is one of the most important limiting environmental factors to the survival of first year seedlings. Seedling mortality appears to result more from severe drought in the upper 6 in. (15 cm) of soil than from infertility or soil chemical toxicity. Greenhouse bioassay studies of the acid spoil show no effect of soil chemistry problems on seedling emergence or short-term survival. Simultaneous measurements of leaf and soil water potentials of plants during 1975 clearly show that severe water stress is commonly experienced by plants on McLaren Mine spoil material, but not by those growing on undisturbed tundra. At least part of this effect is due to the lower water holding capacity near the surface of the rocky mine spoil materials. Intensive research on seedling water relations of both native and introduced species is continuing.

Additional plant physiology research is vitally needed to support on-going rehabilitation programs. Virtually nothing is known about the physiological requirements and limitations of most alpine plant species, particularly as they are affected by heavy metal toxicity, mineral deficiencies in the soil, drought resistance, and the role of insect pollinators on the enhancement of plant vigor. Recently, Billings (1974b) reviewed the major features of alpine plant adaptability, but little data are available to quantify their magnitudes. Generally, however, it can be concluded that the seedling stage of development is more susceptible to environmental stress than are mature plants. Also, the combination of water stress, mineral deficiencies, and heavy metal toxicities are the principle limiting factors to the establishment of a plant cover by conventional seeding methods on alpine disturbance.

Microclimatic Research

Several microenvironmental studies are being conducted on the McLaren site. Two battery powered data loggers were used during the 1975 field season to record radiation, wind, humidity, air temperatures, soil temperatures and soil water potentials. These data are being used to contrast the microclimate on spoil dumps with that on undisturbed tundra and to relate plant survival and growth to these microclimatic factors. Other studies will evaluate the effect of mine dump configuration and various geometric surface patterns to achieve desired changes in microclimate and snow accumulation that would enhance revegetation efforts and the hydrologic regimen of the site.

The primary microenvironmental factors contrasting disturbed sites from undisturbed tundra are soil water potential, soil temperature, and air temperatures near the soil surface. Soil water potentials and soil temperatures on mine spoils are far more variable, particularly near the surface, than on adjacent undisturbed areas. Spoil material tends to dry more quickly than undisturbed soil, and to reach lower levels of water potential, often exceeding -20 bars in the upper 6 inches (15 cm). Soil temperatures are generally higher on spoil material, and the surface temperatures may exceed those on undisturbed areas by 10 to 15°C. Air temperatures near the soil surface are also generally warmer, although the extremes are considerably moderated by convection.

Water Quality Research

The quality of both on-site and drainage water can be seriously affected by mining activity and other types of surface disturbance. These changes in water quality can effect the aquatic environment, cause mortality of off-site plant communities within the drainage pattern and may inhibit vegetation establishment on disturbed areas. Each of these problems is demonstrated at the McLaren Mine site.

Soil water quality within the rooting zone is being monitored on the mine disturbance and adjacent undisturbed areas. The exposure and subsequent oxidation of pyritic material during mining has appreciably increased the acidity, heavy metal, and sulfate concentrations in near surface water. For example, soil water solutions on undisturbed areas had a pH of about 5, specific conductance of 61 mhos/cm, 1.0 mg/l iron, and 15 me/l sulfate. Samples from the mine site had a mean pH of 2.3, specific conductance of 12,000 mhos/cm, 600 mg/l iron and 3000 me/l sulfate. Monitoring will be expanded as site rehabilitation progresses to evaluate rehabilitation practices on near surface water quality.

A cooperative study of surface and groundwater quality is being conducted by the Montana Department of Natural Resrouces, Environmental Protection Agency and USDA Forest Service. Monitoring will be continuted to assess rehabilitation effects on these water resources.

RECOMMENDATIONS FOR REHABILITATING ALPINE DISTURBANCES

The results of the research programs on the Beartooth Plateau so far indicate that a number of recommendations for rehabilitation of alpine disturbances can be made. Although the research has been active for only three growing seasons, the need for answers to rehabilitation problems are desparately needed by land managers and by private industry. Realizing that research of this nature in alpine environments may require much longer periods of time to establish definite results, the following recommendations are based on the best available data.

Species Selection

A survey of the native and, if present, introduced species growing on disturbances in the area to be rehabilitated is recommended. Seed collection of these species should be restricted to local populations to reduce the chances of incorporating unadapted genetic material. For alpine disturbances on the Beartooth Plateau, the species listed above (Revegetation Research) are recommended. However, other species may also be adapted, particularly in different alpine areas. Care must be exercised to collect the seeds only after they have matured in the seed heads since collections too early will reduce viability. If possible, seed viability should be determined so that seeding rates can be determined on a whole live-seed basis.

It is recommended that mixtures of both native and introduced species be used on alpine disturbances. These mixtures will accomplish at least two major objectives of revegetation: 1) it will provide cover and forage more quickly than mixtures of just native species, and 2) it will provide for the eventual occupation of the site by natives more quickly than natural invasion.

The concept of vegetation baseline studies (Ward, 1974) prior to revegetation is recommended. Alpine and subalpine environments represent the near ecological limits of many species, and spatial environmental gradients are particularly important. Subtle variations in topography and soils may have profound effects on successional patterns and on local populations of adapted species.

Seeding Methods

Seeding of alpine disturbances should be done only in the late fall, particularly if native species are included in the mixture. Late fall seeding insures that the requirements of plants are met and that the seed will be exposed to optimum environmental conditions the following spring during snowmelt. Alpine areas are generally inaccessible until late spring, at which time conditions may not be favorable for germination and survival. Also, fall usually provides more favorable working conditions for planting.

The soil surface of the site should be loosened by ripping, rototillering, harrowing, or raking to facilitate intimate contact between the seed and soil, and to improve the hydraulic aeration, conductivity, and other soil conditions. If the seed is then broadcast, the area should be raked and packed firmly. We have found that firm packing, preferably with a seeder-packer, to insure intimate seed contact with the soil is one of the most important steps in a rehabilitation program. Merely relying on snow fall, frost action, wind, or other natural processes to cover and pack the seed following seeding is not recommended. It is also recommended that the seed not be planted any deeper than 0.5 in (1.3 cm), and that the minimum seeding rate be 25 lbs. per acre (28 kg per ha). Substantially higher seeding rates (e.g. 100 lbs. per acre, or 111 kg per ha) may be justified in some cases.

Fertilizer Application

Fertilizer applications are absolutely essential to the successful and rapid establishment of plant cover on alpine disturbances. We recommend that a thorough soil analysis be made to determine the proper fertilizer and application rate for each area. The fertilizer should be applied just prior to seeding, and should be distributed to a depth of a few inches (6 to 7 cm) so that it will be available as the young plants develop. Application rates of about 100 lbs N per acre (111 kg per ha) have been successful on the Beartooth Plateau. Additional fertilizer applications may be required in smaller quantities the following spring or in other years.

Soil Amendments

On acid or pyritic spoils below a pH of about 5.0, it is recommended that lime be applied to a depth of about 6 to 12 inches (15 to 30 cm) prior to seeding. The rate of application will depend upon local soil conditions, but generally about 2000 lbs. per acre (2240 kg per ha) is sufficient to modify the low pH levels we encountered. Highly acidic sites should be tested periodically to determine the possible need for additional lime applications.

Topsoil applications are desirable, but generally it is not readily available in alpine areas. Research results on the Beartooth Plateau indicate that topsoil provides a far more desirable environment for plant growth than raw spoil, but it is not realistic to rely on its availability. The use of other amendments appears to at least partially compensate for the lack of topsoil. Both field plots and laboratory bioassay research indicate that applications of organic matter into the surface soil greatly enhance plant growth and development.

Peat moss, steer manure, straw, or other similar material should be incorporated into the upper 6 inches (15 cm) of soil at a rate of from 2000 to 4000 lbs. per acre (2240 to 4480 kg per ha) prior to seeding. In areas where rapid surface drying is common, a surface mulch of jute netting, straw, or wood fiber may be desirable to reduce evaporation.

Transplanting

Transplanting of whole live plants offers not only a viable alternative to seeding practices, but may also be desirable in combination with seeding. The survival rates of transplants is high, and they provide an almost immediate seed source on disturbed alpine areas. Transplants may not offer adequate erosion control immediately, unless plant spacings are very close. We also need more data on the rate of spread of transplants, particularly in terms of basal area and effectiveness as seed sources.

Research is currently underway to determine the possibilities of growing native species in plastic tubes, similar to modern tree growing techniques, for use as transplants. The development of a deep compact root system and a dense root crown of meristematic tissue in these containers appears to be easily accomplished under greenhouse conditions. Such native grasses as tufted hairgrass, alpine bluegrass, alpine timothy, spike trisetum, and others have been grown in such tubes with no apparent difficulties or adverse effects. Large scale production of such plants would improve the efficiency of planting as well as the economic restrictions usually associated with transplanting.

LITERATURE CITED

Berg, W. A., J. A. Brown, and R. L. Cuany (eds.). 1974. Proceedings of a workshop on revegetation of high-altitude disturbed lands. Colorado State University Information Series No. 10.

Bevan, A. 1923. Summary of the geology of the Beartooth Mountains, Montana. J. of Geology 31:441-465.

Billings, W. D. 1973. Arctic and alpine vegetations: similarities, differences, and susceptibility to disturbance. BioScience 23:697-704.

Billings, W. D. 1974(a). Adaptations and origins of alpine plants. Arctic and Alpine Res. 6:129-142.

Billings, W. D. 1974(b). Arctic and alpine vegetation: Plant adaptations to cold summer climates. In J. D. Ives and R. G. Barry (eds.). Arctic and Alpine Environments. Harper and Row, N.Y. P. 403-443.

Billings, W. D. and H. A. Mooney. 1968. The ecology of arctic and alpine plants. Biol. Rev. 43:481-529.

Brown, R. W. and R. S. Johnston. 1976. Revegetation of an alpine mine disturbance: Beartooth Plateau, Montana. USDA Forest Service Res. Note INT___.

Johnson, P. L. and W. D. Billings. 1962. The alpine vegetation of the Beartooth Plateau in relation to cryopedogenic processes and patterns. Ecol. Monog. 32:105-135.

Johnston, R. S., R. W. Brown and J. Cravens. 1975. Acid mine rehabilitation and problems at high elevations. Proc. ASCE Watershed Manage. Symp., Logan, Utah. p. 66-79.

Love, D. 1970. Subarctic and subalpine: where and what? Arctic and Alpine Res. 2:63-73.

Loverling, T. S. 1929. The New World or Cooke City Mining District, Park County, Montana. Contrib. Econ. Geology, U.S. Geol. Surv. Bull. 811. p. 1-87.

Marr, J. W., D. L. Buckner, and D. L. Johnson. 1974. Ecological modification of alpine tundra by pipeline construction. In: W. A. Berg, J. A. Brown, and R. L. Cuany (eds.). Proceedings of a workshop on revegetation of high altitude disturbed lands. Colo. State Univ. Inform. Series No. 10. p. 10-23.

Nimlos, T. J., R. C. McConnell, and D. L. Pattie. 1965. Soil temperature and moisture regimes in Montana alpine soils. Northwest Sci. 39:129-137.

Plummer, A. P., S. B. Monsen, D. R. Christensen. 1966. Intermountain range plant symbols. USDA Forest Service. Intermountain Forest and Range Experiment Station, Ogden, Utah. 69 p.

Sullivan, G. V. and G. F. Workentine. 1964. Beneficiating low-grade chromites from the Stillwater Complex, Montana. USDI, Bureau of Mines.

Thilenius, J. F. 1975. Alpine range management in the western United States - principles, practices, and problems. USDA Forest Service, Res. Pap. RM-157. 32 p.

Willard, B. E. and J. W. Marr. 1970. Effects of human activities on alpine tundra ecosystems in Rocky Mountain National Park, Colorado. Biol. Conserv. 2:257-265.

Willard, B. E. and J. W. Marr. 1971. Recovery of alpine tundra under protection after damage by human activities in the Rocky Mountains of Colorado. Biol. Conserv. 3:181-190.

Ward, R. T. 1974. A concept of natural vegetation baselines. In: W. A. Berg, J. A. Brown, and R. L. Cuany (eds.). Proceedings of a workshop on revegetation of high-altitude disturbed lands. Colo. State Univ. Inform. Series No. 10. p. 2-4.

DEVELOPMENT, USE AND POTENTIAL OF CONTAINERIZED SEEDLINGS

Marvin D. Strachan
Nursery Manager
Colorado State Forest Service
CSU Foothills Campus
Fort Collins, Colorado 80523

ABSTRACT

Bare root nurseries produce acceptable forestation planting stock in the Rocky Mountains and Plains under severe conditions of environmental stress. A new seedling has a difficult time growing and surviving in the nursery bed for two to three years in order to get large enough for field planting. Production time from seed to a plantable potted tree seedling has been reduced from three years to one year as a result of research conducted at the Colorado State Forest Service Nursery. A greenhouse facility constructed to control temperatures, humidity, photo period, nutrient application and carbon dioxide content has produced evergreen seedlings over 24 inches tall during a one year cycle.

For nearly one hundred years land managers have recognized the need and advantage of planting trees and other woody plants for reforestation, watershed management, erosion control, wildlife habitat and environmental protection. Nurseries for the production of bare root seedlings exist in every state in the United States and are presently producing in excess of two billion seedlings annually with about one-half being used for forestation and conservation projects and one-half being used for landscape and aesthetic use.

At today's prices, it would cost in excess of one and one-half million dollars to develop and establish a 320 acre nursery for the production of five to ten million bare root seedlings annually. This would include seed collection and extraction facilities, seed and seedling storage facilities, machinery and administrative housing, equipment purchase and irrigation systems.

A great deal of technical knowledge and technique has been developed during the past 75 years in the nursery management profession and operation of bare root forest nurseries. Such techniques are now quite normal operations and are geared to create the most favorable environment to obtain the highest quality seedling in the least amount of time and at the lowest possible cost. Such practices involve seed collection, extraction and cleaning of a wide range of species--both deciduous and coniferous, pre-germination stratification, seeding densities and depth of seeding, fertility manipulation, irrigation schedules, chemical and mechanical weed control, proper use of fungicides, insecticides, pre-emergence herbicides, post-emergence herbicides, miticides, growth regulators, root pruning, induced hardening procedures, lifting schedules, grading standards and techniques, over winter refrigerated storage and shipment for field planting.

Bare root techniques have amply demonstrated that the larger and older the seedling, within limits, the greater will be its probability of surviving drought, rodents and vegetative competition. For conifers, a two year or three year old seedling provides the best compromise between cost and field performance.

Even under the best management conditions, bare root systems are highly vulnerable to uncontrolled nursery environments. The best nurseryman is at the mercy of seasonal weather fluctuations. Periodic crop failures are accepted as being as unavoidable as changes in the elements.

Notwithstanding these inherent disadvantages, the bare root system backed by good nursery practice, well organized distribution and high quality planting can be an adequate forestation method. It fails where lack of knowledge or indifference violates principles of good crop production, where inadequate organization abuses seedlings in transit, or where poor planning and supervision results in low planting quality.

Recent years have seen something of a revolution in the growing of seedling trees through the use of containerized planting systems. Two systems of containerization have both proved advantageous as a means to supplement bare root production. The first system requires that a field grown seedling of adequate size, usually two years old, be placed in a container or tube with soil as a potting mixture for at least one year's further growth and root establishment. This system requires at least three years time, a large labor force, a semi-controlled environment, shade house for the growth period after potting, and special potting machines. The potting operation is limited to the dormant periods of early Spring (April) and early Fall (October) and is fully dependent of the successes or failures of the bare root nursery production techniques. The second containerized system produces a seedling from seed at an accelerated growth within a controlled environment greenhouse. This production method will be discussed in more detail. Container production of forest and conservation type trees in the United States has increased from less than 500,000 in 1965 to more than 75,000,000 in 1975. Most of the present day production (44,000,000) is in Douglas fir in Washington and Oregon.

Since the mid 1950's, the Colorado State Forest Service has been growing seedling trees and shrubs for conservation and reforestation purposes and distributing them to rural Colorado landowners. During 1975, over 1,500,000 seedlings were distributed to over 3,600 landowners. Of this total, 320,000 were potted evergreens.

Potted evergreen seedlings have been in great demand in the Rocky Mountain and Plains states for many years. In recent years a serious shortage has occurred. To attain a potted evergreen seedling of sufficient topheight, root structure and stem caliper to overcome environmental stress of the planting site, it has been necessary to grow the tree a minimum of three years. After seed is sown in nursery beds, a two year period is required to attain a seedling large enough to pot. The two year old evergreens are potted in 2" x 2" x 7" tar paper pots with mechanical machines and then placed in a lath house for one further year of growth to establish an undisturbed root system. Thus, this type of potted evergreen is ready for field planting after a three year growth period.

In order to attain a larger quantity of potted trees and to overcome the many problems in field growing evergreens from seed, other production methods were investigated. Research by Kozlowski (1968), Tinus (1970), Mathews (1971), indicated that it was possible to grow seedling trees in a controlled environment.

During the winter of 1972-1973, the Colorado State Forest Service purchased the necessary structural components, controls and supplies and materials for just under $10,000 and erected a 27' x 100' double layer polyethylene air inflated greenhouse. On April 10, 1973, 50,000 2" x 2" x 7" tar paper pots were seeded as follows: Colorado blue spruce--25,000; Douglas fir--13,000 and White fir--12,000. After eight and one-half months of growth, the seedlings exceeded fourteen inches topheight with some in excess of twenty four inches topheight.

In April, 1974, 46,000 or 92% of the seedlings grown in the controlled environment greenhouse were shipped to non selected rural landowners for planting. A 5% evaluation check was made in seven Colorado counties during August and September, 1974. In all cases the greenhouse grown trees survived as well or better than the three year old potted trees or three year old bare root stock. Even during the very dry 1974 growing season all plantings which were maintained well enough to evaluate showed the greenhouse grown trees survived in excess of 50%. Most planting indicated between 80% and 85% survival with several 100% survival.

PRODUCTION PROCEDURE

To be able to grow container stock rapidly in a controlled environment some nursery production experience is necessary and one must learn as much as possible about the physiology of the tree, what the optimum growth environment is and how to regulate its growth. A growing cycle must be designed to produce a tree of the desired size in the proper physiological condition ready for planting at a specific date. Since the growth habit of most species of trees and shrubs is different from that of another given species, each species will require a different environment and separate optimum conditions for growth.

CONTAINER AND POT MIX

The container size should be determined by the size of the tree to be grown. The top growth should not exceed the root growth by more than a three to one ratio by weight or by volume. Since Colorado windbreak and reforestation planting conditions require a rather large evergreen seedling--6" to 18" topheight, 6/32" caliper and at least 7" depth of rootball--a 2" x 2" x 8" tar paper or plastic pot (approximately 30 cubic inches) was selected.

The container should be impermeable to roots while in the nursery and immediately permeable to roots upon outplanting or the container should be removed without disturbing the root system. The container should have an opening at the bottom for root egress to prevent balling up and should have very little taper to allow root development in the lower portion of the root ball.

The pot mix should have a high water retention capacity and yet be well aerated. The pot mix should be light in weight, have adequate exchange capacity, should not promote the growth of pathogens and should not be affected by mineral nutrition. A mixture of organic peat moss, vermiculite or perlite are good pot mix.

Mycorrhizal fungi are necessary for adequate root development. Two to five per cent forest duff should be added to the pot mix to inoculate the root cavity with mycorrhizal fungi.

THE CONTROLLED ENVIRONMENT

Young seedlings under optimum growing conditions will grow faster the larger they get because of enlarged photosynthetic area. Height growth regimes should be maintained until the trees are as tall as desired. Leader growth is then stopped and growth is concentrated on lignification and diameter of stems and roots. Finally, the seedling is conditioned physiologically (hardened) for outplanting.

TEMPERATURE

Day and night temperatures vary with species and it is important to know the optimum combination for the species desired. For Colorado blue spruce, optimum temperatures of 70 degrees F. during the day and 75 degrees F. at night are the best during the growth period.

An automatic staged control system with cooling pads, exhaust fans, heaters and air circulation will provide the proper temperature regime.

During mid summer when temperatures are very warm and solar sun rays are at their maximum temperature it may be necessary to add some artificial shade to help cool the greenhouse. This can be done by covering the greenhouse with a 50% saran shade-cloth.

HUMIDITY

A rather high humidity is desirable because moisture stress on the trees is reduced, the stomata remain open longer to assist photosynthesis, and the trees require less watering. Humidity must not be so high that the foliage remains wet from irrigation for extended periods as molds and mildew will develop as well as the growth of moss.

Humidity range between 50% and 70% is recommended during the growth period.

PHOTO PERIOD

From germination until the trees are grown to their full height they need supplemental light at night. Supplemental light is not for additional photosynthesis but only to prevent night dormancy.

For growing Colorado blue spruce, 10 watts per square foot of bed space or about 60 foot-candles of incandescent light with a 7% on cycle during the night hours will provide maximum growth.

NUTRIENT APPLICATION

Since the potting mix is nearly sterile, a complete complement of mineral nutrients must be added through the irrigation system. Most species vary in their requirements for the various mineral nutrients. The following chart shows the approximate concentration of mineral nutrients applied with each weekly irrigation.

Element	High N, P, K solution parts per million	Low N High P, K Solution
N	225	40
P	27	80
K	155	120
Ca	60	60
Mg	48	48
S	63	63
Fe	2.5	2.5
Mn	.5	.5
Cu	.3	.3
Zn	.3	.3
Cl	.03	.03
Mo	.007	.007

While the seed is germinating, no nutrients are applied which helps prevent damping off and growth of moss and algae. The moisture in the pots should be maintained near field capacity but watered infrequently enough to allow root transpiration. PH and conductivity should be monitored throughout the growth period.

The nutrients, as purchased in granular form, can be mixed into solution form with water and injected into the irrigation line. The stock solutions are stable but will precipitate if mixed in concentrated form.

CARBON DIOXIDE ENRICHMENT

All green plants require carbon dioxide. In a closed greenhouse the CO_2 concentration can be increased from a normal atmosphere of 300 ppm to 1800 ppm with an increase in dry weight growth of Colorado blue spruce of 50 to 70 per cent.

Carbon dioxide can easily be increased with a natural gas or propane gas generator. The early morning hours--one hour before sunrise and two to three hours after sunrise is the most productive time to enrich the atmosphere with CO_2 as the plants are best able to absorb the gas.

HARDENING PERIOD

When the seedlings reach a desired full size, the hardening process begins. A nutrient and moisture stress is applied to stop height growth. This is done by leaching thoroughly with water and then allowing the pots to dry longer than usual. Supplemental light is shut off. Then they are rewatered with a low nitrogen, high phosphorus, potash nutrient solution. The short day and moisture and nutrient change initiates bud set. Temperatures are reduced from 72 degrees F. to 55 degrees F. for an additional five weeks to allow stem diameter growth, lignification, root development and bud set. After five weeks of hardening, the temperature is reduced to just above freezing. The chilling requirements are met for spring bud break and full cold hardiness is developed. The trees are ready for removal from the greenhouse to a lath house until shipped to the field.

While the experience with container stock has been limited to a few thousand plants at high altitude elevations over 8,000 feet in Colorado and accurate survival data is not available, it is quite sure that survival and growth data of containerized stock versus bare root stock available in other areas of the United States would follow a similar pattern in the Rocky Mountain Area. Container stock has consistently shown a 20 to 25 per cent survival gain over bare root stock. In addition to a survival gain, there are a number of reasons for use of containerized seedlings:

1. Nursery sites are expensive, scarce, and take much time to develop; container production requires less space and site is not as critical.

2. Containerized production is a rapid, flexible means to increased demand for seedlings.

3. Containerization can be used to produce species slow or difficult to grow in bare root nurseries, or difficult to keep in good condition during handling, transporting or field planting. This facet is important to high altitude planting because many adaptable species are very slow growing, have inadequate root systems and perform very erratic in lower elevation nurseries.

4. Containers will extend the planting season. Well conditioned stock can be made available at times often not available now from bare root nurseries. The planting season can be lengthened further into the growing season because of an established root system and the lack of transplant shock.

5. The planting season can be lengthened to permit planting with a smaller and more stable work force.

6. Container stock will provide greater production and planting efficiencies for a number of reasons:

a. Seed can be used more effictively, particularly high value genetically improved seed.

b. Fertilizers, fungicides, insecticides and miticides can be applied and regulated more readily and efficiently.

c. More uniform stock is produced.

d. The whole containerized process lends itself to mechanization and thus labor reduction.

e. Facilitate planting in rocky ground or among residues.

f. Keep seedlings in good condition more easily if there are delays in planting.

g. Root exposure is lessened and thus survival is increased.

h. Less damage to tops and roots during transportation.

i. Containers keep 100% of the root system, constrain the root at one stage, then let it go free at another stage with the objective being to shape roots, protect roots and to control egress of roots from the container case.

j. The container carries a reserve supply of moisture in the root ball.

k. The container can be designed to develop a deep root system for planting on dry sites where the top four to six inches might be quite dry.

These sometimes theoretical advantages of container stock are clearly evident; the challenge is to get them in actual practice.

CONCLUSION

Looking ahead, containerized seedlings seem destined to play an increasingly important role as a forestry tool in the Rockies and Plains. Notwithstanding the large numbers of containerized seedlings currently being produced in so many places, the technology is still in its infancy. A continuing strong research program in this field is absolutely essential. The system is a new concept for forest nurseries and a real break through for nursery production. The potential has hardly been tapped and in the near future (three to five years) much more will be known and advance planning will be possible so that vast quantities of containerized seedlings of superior quality will be available.

SPECIAL NEEDS AND PROBLEMS OF HIGH-ALTITUDE REVEGETATION IN NATIONAL PARKS

David R. Stevens
National Park Service

INTRODUCTION

Revegetation problems in national parks exist as a result of the unique aspects of the resource which must be maintained to meet the management objectives of the area. In any one national park, we may have various land uses which entail different management objectives. Although the major portions of the land are classified as the natural zone, this can be broken down into various sub-zones that require even more refined management, and possibly more specific revegetation needs.

Revegetation is needed because of some disturbance to the natural scene. The disturbance may be historic, prior to the park; intentional, as a result of development; or incidental to public use of the area. In very few cases in natural areas of the park system will the objective of revegetation be only to prevent erosion or obtain a ground cover. Generally the objective is to reestablish a semblance of the natural ecosystem with esthetics and prevention of erosion key by-products. In order to accomplish this mission with some uniformity across the park system, certain legislative and political constraints have been developed.

CONSTRAINTS

The mission of the National Park Service is best stated in the 1916 Enabling Act, "...which purpose is to conserve the scenery and the natural and historic objects and the wildlife therein, and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations."

This is to say that the diverse national treasures that are the resources of the national parks are entrusted to the park service to be passed on unimpaired to future generations. The mission is above all a command to perpetuate those inherent qualities for which the park was established. In many cases the vegetation may be an important aspect and major reason for the park's establishment. In all cases it is a part of an ecosystem which has evolved as the basic unit of management.

Management of the vegetation must be related to the objective for use of the land area. A system of land classification has been developed for management purposes. Four general zones are recognized that may be present in any one national park; natural, historic, development, and special use.

Natural Zone

Natural resources and processes remain essentially unaltered in the natural zone. Revegetation is directed toward duplicating or restoring the natural vegetation composition and structure. This zone may also have sub-zones such as wilderness where the vegetation must be managed to retain the wilderness character. In the environmental protection zones (formerly research natural areas) it is hoped to minimize impact and retain scientific value without the need of restoration. In the case that revegetation is necessary, all efforts must be made to preserve the scientific value of the area. These areas are the baseline (control) areas for the rest of the park's ecosystem.

In addition, there are also outstanding natural feature sub-zones and the natural environment sub-zones which encompass the remainder of the natural area.

Manipulation of terrain and vegetation may be carried out in natural zones to encourage, simulate, or restore natural conditions on lands altered by human activities. As stated in the National Park Service Management policies, this may be done through, but not restricted to, the following techniques:

1. Removal of man-made features, restoration of natural gradients, and revegetation with native park species on acquired inholdings and sites from which developments have been removed.

2. Rehabilitation and maintenance of areas impacted by visitor use including redesign, relocation, or removal of facilities to avoid or ameliorate adverse visitor impacts on the ecosystem.

3. Restoration to the natural appearance of areas disturbed by fire control activities.

4. Restoration of landscape altered by human activities prior to park establishment.

Plant species exotic to the natural ecosystem will not be utilized or introduced in revegetation within the natural zone.

Historic Zone

This zone includes all lands managed for their historic significance. All vegetation including trees shall be managed to reflect the general visual aspect prevailing during the historic period. Exotic species, not native to the park but that are a desirable part of the historic scene, may be introduced and maintained.

Development Zone

This zone includes lands where non-historic development and intensive use may substantially alter the natural environment. Management of the landscape and vegetation will be commensurate to the greatest extent possible with the primary purpose of the park. It often must effect a transition from the developed intensive use area to the natural zone. Exotic plants may be used to carry out these objectives; however, native species are preferred. If it is shown that the revegetation can only be accomplished with exotic species, all efforts will be made to determine that they will not become pests.

Special Use Zone

Special uses of land and water not permitted in natural, historic, or development zones are included in this category. They mostly relate to recreation areas. Special management of the landscape can be carried out to meet the objectives of the area. Constraints are generally similar to developed areas.

Another constraint to revegetation should also be mentioned. In the designated wilderness areas the use of motorized equipment is limited. Therefore, restoration programs that involve back country trails and campsites must be carried out primarily utilizing hand labor. Transportation of men and equipment will also have to be essentially limited to horses.

ROCKY MOUNTAIN NATIONAL PARK

In order to put this all into perspective with respect to the subject of this conference on revegetation of high altitude lands, let's look at Rocky Mountain National Park.

Rocky Mountain National Park is essentially a high elevation park. The mountains and the high elevation ecosystems are the resource that are to be perpetuated. Specifically, the alpine tundra is one of the major resources and one which is quite vulnerable to destruction by visitor use. As stated by Willard and Marr (1970), "No civilized society has learned how to add man to the landscape without robbing subsequent generations of resources and opportunities that are vital to their well being." No matter how we attempt to protect the park environment, in allowing visitors to appreciate the wonders of the park, some damage to the vegetation is entailed.

In the natural zone, there are numerous sources of disturbance that may require revegetation. The fact that a major portion of the park lies above 11,000 feet elevation only magnifies the seriousness of the damage and the difficulties in trying to repair it. Concerning the alpine tundra, Willard and Marr (1971) stated, "The kobresia meadow ecosystem is resistant to disturbance because of its strong turf. However, once the turf is broken, the erosion processes generally remove the entire humus, enrich soil horizons, and leave the surface covered with coarse gravel. Secondary succession, back to the climax kobresia is tediously slow...Studies indicate that it will take at least several hundred and possibly a thousand years for ecological processes to produce a persistent ecosystem in some areas modified by visitor activities on Trail Ridge tundra." Trampling of the alpine tundra by visitors is a common and ongoing source of disturbance at Rocky Mountain National Park. In these high elevation areas, it presently presents the greatest challenge to revegetation practices.

However, disturbance by visitor trampling is not only significant in the alpine. In the sub-alpine ecosystems it may also be severe. Most of the back country campsites are designated in this zone. About 265 sites receive the impact of over 50,000 campers annually. Damage to the vegetation in the immediate vicinity of these areas is especially severe. These areas are in the back country, most of which is recommended for wilderness. Here we must maintain vegetation as much as possible, revegetate the abandoned sites and sites with excessive damages, generally without the aid of power equipment.

Also in the back country we have trail obliteration, changes in alignment, and rerouting, which result in the need to revegetate the old scars. Water erosion in these cases due to the character of the mountain soils is especially severe if ground cover is not reestablished.

Most of the lower parks and meadows in Rocky Mountain were homesteaded prior to 1900. In addition to grazing these areas intensively, much of the land was irrigated and even cultivated. Most of the buildings have been removed, but many of the sites need further restoration. The homestead period was followed shortly by the development of mountain resorts. These areas were severely impacted and some have been eliminated only recently. The major ones included Spragues Lodge, Steads Ranch, Bear Lake Lodge, Brinwood and Fall River Lodge on the east side of the park; Holzwarth and Green Mountain Lodge on the west side. Most of these buildings have already been removed but some are still being used as park service quarters. As quickly as possible, however, they are being phased out as indicated by 14 cabins in Hallowell Park being removed this year. Except for development of the trailhead parking and a small picnic area, the entire Hallowell Park site, including the road maintenance area, will be restored to contour and revegetated.

Road cuts and fills still are in need of considerable restoration. This is especially true along Trail Ridge Road, although much work was done in this area many years ago. In any new construction, such as the new sewer system which extends into the park in several locations, revegetation is required along the route. In Moraine Park this entails about 1-1/2 miles of the line route and two sewage lagoons near the Moraine Park Campground which will be eliminated.

The intensive use given the roadside campgrounds and the resulting resource deterioration was documented by Papamichos (1966). Periodic revegetation and the use of plantings to channel use has been recommended, but little progress has been made toward this end.

The amount of restoration and revegetation work that is required annually could develop into a major program for the national parks. Unfortunately funds are not available to do all of the work required and often priorities must be set up.

HISTORY OF RESEARCH AND REVEGETATION EFFORTS

Attempts at restoration and revegetation were initiated as early as 1933 in Rocky Mountain National Park. The relocation of several low elevation roads and the construction of Trail Ridge Road presented the needs. The establishment of two Civilian Conservation Corps camps provided the manpower to accomplish the work. At about this time several homesteads were also acquired that required restoration work.

The early efforts were almost entirely a transplanting program. These included both shrubs and tree transplants along with laying sod. Shrubs and trees were planted along the Bear Lake Road to both stabilize the banks and to obliterate the old road cut.

One of the major efforts was the sodding of about one and one-half acres along a road cut on Fall River Road in 1934. In this case, a very steep cut was boarded with scrap 1x4's and staked to hold the sod. They had to build wooden platforms on which to stand while they put down the vegetation. After sodding the area was well watered. This project was very successful, and the establishment of the sod was so well done that even today no trees have been able to establish themselves on this slope. The success of this project led to many other slope stabilization efforts using hand laid sod.

In August, 1938, native seeds were collected under the supervision of Dr. H. D. Harrington of Colorado State Unviersity. The seed was planted in plots along Trail Ridge Road from 9500 feet at Hidden Valley to 11,800 feet on twenty two plots in September and October. When reported on by Harrington (1946) the experiment was considered a success. Of twenty four species tested, fifteen seemed to offer particular promise. Unfortunately, we have no records of the exact location of these plots today.

In 1941 one of the most interesting experiments was made in revegetation of the alpine tundra. Approximately 21,000 square yards or two thirds of the back slope of Trail Ridge were "spot sodded." Records show 8700 mandays of CCC labor was used to lay tundra sod in spots and strips along Trail Ridge Road. The records are unclear as to the exact technique, but vegetative reproduction was expected to fill in the spaces between the spots. However, today both the spots and strips can be seen essentially as they were laid. Why this technique did not work can only be surmised today.

In 1958 the availability of funds presented the opportunity to study ecosystems of the park and to determine the nature and degree of effect of visitors (Marr and Willard, 1970; Willard and Marr, 1970). A five-year study was initiated by Dr. John Marr and Dr. Bettie Willard with emphasis on the alpine tundra. Besides providing excellent data on where and what impact visitors were having, specific data on recovery rates of the tundra without man's aid was obtained. Two human exclosures were established on Trail Ridge Road in order to make these measurements. As it relates to this conference, their observations illustrated that in the alpine environment it is necessary to have a succession of favorable seasons in order for seedlings to develop into mature plants. Several environmental factors, although severe under normal conditions on the tundra, become more severe on areas devoid of vegetation and tend to retard plant establishment (Willard and Marr, 1971). These were primarily erosion by wind and water, activity of frost, and increased soil temperatures. Survival of seedlings was better on the B and C horizons rather than in the organically rich A horizon.

Studies by Greller (1974) of road cuts and slopes indicated that plant succession played a minor role in revegetation of the tundra. The important processes were first the stabilization of the slopes by pioneer grasses and second, the occupation of interstitial bare areas by mat and cushion plants. His findings indicated extensive human assistance was necessary if road cuts were to be revegetated. Controlling factors were the stability of the slope. Public education was also recommended.

In 1969 a short area of cut slope in the sub-alpine zone above Hidden Valley was restored with two treatments in an attempt to determine a good way to proceed with stabilization of these areas. One site was laid back to the angle of repose at one and a quarter to one. This required considerable cutting of trees above the slope and removal of fill material. The other treatment built up the slope by using wire gabions to a one half to one slope. Both areas were topsoiled and seeded in the fall. No effort was made to hold the soil against winter winds, and therefore by spring most of the topsoil was gone along with the seed. Vegetation establishment has therefore been very slow, but today some vegetation has finally developed at the lower edge of both treatments.

Another study in 1968 by Gary Jollif attempted to determine techniques of revegetation of deteriorated sites at three roadside campgrounds. These are in the upper montane and the subalpine zones. His findings showed critical factors to plant establishment were available nitrogen and soil moisture. Unfortunately all of his revegetation efforts were done with exotic species.

Presently the availability of a site when the rock cabins were removed from Trail Ridge has led to an extensive study of techniques. Using research results from all aforementioned studies and revegetation efforts, a plan of experimental plots was worked out. Effect of water and wind erosion is being reduced through snow fences, burlap mat, and aspen mat. Topsoil has been added on several plots and mulch with a seed source to others. Fertilizer was added to some of the plots. All were treated in September, 1975 and water was added at that time. There has been no results determined of the treatments at the present time.

The primary objective of this experiment is to arrive at a standard technique to restore disturbed alpine areas in the park.

Research on revegetation in high elevations in other national parks has been fairly limited. Some of the best work is being done by J. W. and M. M. Miller in North Cascades National Park (Miller and Miller, 1975). Their primary contribution has been on the technique of starting alpine plants at lower elevations and transplanting them to the disturbed site after establishment.

CONCLUSION

The outcome of about forty years of revegetation efforts in Rocky Mountain National Park and other national park service areas is that to restore high elevation lands requires considerable efforts and assistance by man. The constraints of the park service policies, especially in the alpine, have not been considered a major hindrance, although they require special attention.

Primarily in the case of the alpine, but also at lower elevations, we find that the best management is protection of the resource before damage exceeds what is naturally reparable. In the case of visitor trampling, this is being accomplished by channeling the visitor activities with fences, paved walkways and trails. Only recently we have been considering board walks, steel grid walks and planting of shrubs to direct the use. However, we realize some damage is still going to occur and periodic restoration will be necessary.

Experience has demonstrated that transplanting natural tundra turf (from a similar site) is the most successful technique. The major problem is that there is no source of tundra turf for transplanting purposes. Without tundra for transplanting, we still have to work out techniques to regenerate alpine tundra. This is the major challenge which we are working on today. Our present techniques are fairly effective in the lower elevations, but we have not satisfactorily been able to revegetate tundra.

LITERATURE CITED

Greller, A. M. 1974. Vegetation of Road Cut Slope in the Tundra of Rocky Mountain National Park, Colorado. Biol. Conserv. 6(2):84-93.

Harrington, H. D. 1946. Results of a Seeding Experiment at High Altitudes in the Rocky Mountain National Park. Ecology 27(4):375-377.

Jollif, G. D. 1969. Campground Site-Vegetation Relationship. Ph.D. thesis, Colorado State University, Fort Collins. 139 pp.

Marr, J. W. and B. E. Willard. 1970. Persisting Vegetation in an Alpine Recreation Area in the Southern Rocky Mountains, Colorado. Biol. Conserv. (2):97-104.

Miller, J. W. and M. M. Miller. 1975. Revegetation Experiments on Cascade Pass, North Cascades National Park, Washington. Unpublished report (typewritten). 8 pp.

Papamichos, N. T. 1966. Light, Soil, and Moisture Conditions in Areas of Heavy Recreational Use. M.S. thesis, Colorado State University, Fort Collins. 101 pp.

U. S. Department of the Interior, National Park Service. 1975. Management Policies. 126 pp.

Willard, B. E. and J. W. Marr. 1970. Effects of Human Activities on Alpine Tundra Ecosystems in Rocky Mountain National Park, Colorado. Biol. Conserv. 2(4):257-265.

Willard, B. E. and J. W. Marr. 1971. Recovery of Alpine Tundra Under Protection after Damage by Human Activities in Rocky Mountain National Park. Biol. Conserv. 3(3):181-190.

REVEGETATION AND STABILIZATION OF ROADSIDES ON VAIL PASS

Jim Gregg
U.S. Forest Service
Minturn, Colorado

The area usually referred to as Vail Pass encompasses a 14-mile stretch of roadway between Copper Mountain and Vail, Colorado. The high point is 10,500 feet; the low point is 8,400 feet producing an elevation change on the Vail side of 2,100 feet. Construction of a major four-lane highway system and its accompanying revegetation and stabilization problems has been, and still is, a challenging task.

Vail Pass revegetation and stabilization problems are unique in many ways. The highway basically bisects five ecosystems -- Engelmann spruce-subalpine fir, lodgepole-aspen, shrub, wet meadow, and dry meadow.

Involved are primarily residual-type soils derived from the parent sandstone and mudstone rock of the Maroon Formation -- highly erodiable material that remains in a colloidal suspension when mixed with water. Add to this a growing season near the summit of less than 60 days, a construction season of 5-6 months, a reasonably productive fishery and municipal water supply adjacent to the entire road corridor, and two towns extremely concerned about their environment on either side of the Pass. Needless to say, the problems become ever more challenging.

The work is done by construction contractors who have bid for specific jobs which are usually 1-3 mile stretches of roadway. The work started in 1974 and will conclude in 1978. The Colorado Department of Highways controls and supervises the contractors' operations under direction and funding from the Federal Highway Administration. The entire road right-of-way over Vail Pass is on the White River and Arapaho National Forests thus necessitating Forest Service involvement and stipulations in all matters dealing with land resource protection. Additional agencies that have been involved are the Colorado Division of Wildlife, State Water and Air Quality Control people, and the town of Vail.

Realizing the unique situation and challenge of a high mountain highway construction job over Vail Pass, the subject of this report might better be entitled "ingenuity in Revegetation and Stabilization of Roadsides on Vail Pass." This report will briefly discuss some of the "ingenuity" used on Vail Pass as well as document the more established procedures being practiced.

PLANNING

Planning for revegetation and stabilization is as important as planning the actual road construction. If a unique or specialized consideration isn't in the contract and isn't bid upon by the contractor in his cost and time estimates, it is far more difficult to implement at a later date. Some planning ideas which seemed important in the Vail Pass project are listed below. Ideas such as these also aid the planner in becoming aware of the uniqueness in a particular project.

1. Visit and compare notes with other projects with revegetation problems. Many times someone else has pioneered a new technique or is aware of a problem you will be facing.

2. Geologic investigation is obviously important especially on Vail Pass. One cannot stabilize the roadbank if the entire mountain side has been made unstable by large roadcuts.

3. Soil testing and mapping is important relative to evaluating erosion potential and fertilizer rates and kinds. The sub-surface soil type as well as topsoil sources should be included in the testing and mapping.

4. Informal seed plots established immediately adjacent to the area of anticipated disturbance can be beneficial especially when time permits. Plots can demonstrate directly to the administrators of a project what they will be facing revegetation-wise. It also lets them become familiar with species recognition which might aid successful evaluation on what eventually takes place on the actual job.

5. Local area concerns such as municipal water supplies, fishery resources, and visual considerations all aid in deciding cost-risk ratios. Evaluation from a cost-risk standpoint will also clarify where you might want to stand with new techniques, a new seed, or fertilizer type.

6. Contract size at high altitude is most important. Evaluation must be made if one large project which would basically open up the area for 2-3 years would be less detrimental than a series of small projects each of which may involve disturbances in the corridor of up to 5 years.

7. Contract understanding prior to actually bidding is important relative to allowing for total costs. An inexperienced contractor may not understand what is involved in a 50-foot fill bank which has not yet been brought to grade but must be protected within ten days from possible mountain showers once 30 feet is completed. He may not know

"scarify if a hard pan exists" but may easily identify with descriptions like "seed when soil is moist and fluffy." Displays, drawings, and photos are all invaluable in clarifying contract descriptions.

Once work is underway in high mountain highway construction, more specific project uniqueness is inevitably discovered. A number one consideration here might be "respect the mountains." This might sound like an old mountaineers term but in dealing with characteristics of high altitude stabilization it is necessary. Todays large machinery can cut through a mountain but if, for example, an existing intermittent stream course or a spring is not respected in a cut section, the mountain will gain its revenge.

This is where ingenuity again plays a key role in revegetation and stabilization of roadbanks. The statement "There are no answers only reasonable choices" more than once applies to Vail Pass. Some of the "ingenuity techniques" being used on Vail Pass which gave us some reasonable choices are evaluated below.

1. Slope steepness will vary with the height of the cut or fill sections. Most all slopes on Vail Pass are being layed back to 2:1. In some areas where there are few trees the cuts and fills are laid back to 3:1 or better.

Pro - Flatter slopes are preferable for revegetation.

Con - Additional tree clearing and ground disturbance are involved when slopes are made flatter.

2. Horizontal drilling has been extremely useful on Vail Pass where risk of massive landslides exist. A series of plastic perforated pipe placed in the mountain side to drain underground water lessens landslide risk. This technique has been considered to minimize seepage into cut slopes by gathering underground water and concentrating it in one area.

Pro - This is one of the only techniques known to tap underground water in an undisturbed cut area.

Con - Unless risk of mass land movement is involved, cost may be prohibitative under normal circumstances. It may also be impractical to tap all the intricate patterns of underground water courses which cause most bank seepage problems.

3. Control of underground water seeping out of cut slopes in numerous areas could be the ultimate challenge in high altitude roadbank stabilization. The situation is typical of high mountain terrain especially in the subalpine wet meadow country near the top of Vail Pass. Numerous alternatives exist and the real answer might be a combination of several alternatives.

Permanent wall provides a permanent, one-shot investment solution at high cost. The wall introduces another man-made structure to the mountain scene but eliminates almost all risk of future problems. A partial wall and flatter slopes might be a more economical answer.

Ditching above the cut slope will not normally trap underground water. It can, however, eliminate any surface runoff which would obviously compound the problem of slope seepage during heavy runoff.

Water bars on the cut slope can aid in accumulating water to one spot. Soil conditions must be suitable and periodic maintenance (at least annually) is a must. Native logs can be used to reinforce soil if tied into the slope.

Rock channels aid only if the water problem is centered in one spot. The answer may be to use these in combination with water bars.

A drainage layer made of small rock, covered with topsoil, and revegetated may collect the majority of water seepage.

Large rock placement mixed with topsoil to produce a rock garden effect could be acceptable visually and may allow slightly steeper cuts.

Elimination of topsoil and farming of the natural terrain might eliminate the slip plane effect produced by topsoiling when it cannot be mixed thoroughly with the underlying material.

Continued annual "patch-up" of sluffed areas until eventually enough growth is established that sluffing is eliminated may be the answer if continued funding can be made available.

4. Slope rounding obviously aids in stabilization and revegetation procedures. Fortunately the same technique is a key tool of the landscaping people in their attempt to make the old-fashioned highway slice blend in and appear similar to adjacent natural mountain terrain.

5. Timing of revegetation procedures in high mountain terrain is most assuredly an important consideration. Planting so as to avoid frost heave problems ideally would be July or after mid-September at the higher reaches of Vail Pass. Planting on the Vail project is done within 10 days whenever a slope is completed to grade or if it is a large cut or fill within 10 days after 30 feet is "to grade."

Pro - Planting whenever a slope is completed allows seed to be placed while soil is "moist and fluffy." This also allows mulch to be placed immediately which helps minimize erosion. Due to the variable mountain climate a hard-fast rule on seeding dates may mean little anyway.

Con - One has the risk of early fall frost kill on seed that has just germinated. The option for spot reseeding must be available. Spot reseeding may prove difficult when mulch is in place.

6. Topsoil has been placed on all slopes on the Vail Pass Project. Standards call for a minimum of 4" which is then keyed to the underlying material. This is usually done by the action of a dozer pushing the soil up on cut slopes or by a drag line spreading topsoil on the fill slopes.

Pro - This greatly aids in initial establishment of vegetation.

Con - Topsoil sources are usually in the construction zone. Thus storage areas for the topsoil must be found outside the construction area. Care must be exercised in the use of topsoil material which is excessively high in organic matter. Soil analysis to determine suitability is recommended for topsoil. If the topsoil is not keyed into underlying material a certain risk of slip planing exists especially if the soil is saturated with moisture.

7. Seed rates on Vail Pass are 40 pounds/acre of the following mixture. The seed is raked lightly (1/16 inch in depth) into the topsoil. Each area is measured daily to assure proper rate/area.

Common Name	Botanical Name	% Purity	% Germination	Pounds Pls/Acre
Streambank wheatgrass	*Agropyron iparium*	97	92	7
Western wheatgrass	*Agropyron smithii*	85	70	4
Kentucky bluegrass	*Poa pratensis*	85	75	3
Smooth brome (Manchar)	*Bromus inermis*	85	80	5
Timothy	*Phleum pratense*	99	90	4
Red fescue	*Festuca rubra*	98	85	3
Meadow foxtail	*Alopercurus pratensis*	95	80	4
Slender wheatgrass	*Agropyron trachycaulum*	90	85	5
White dutch clover	*Trifolium repens*	98 1/2	90	5
		Total Pounds/Acre Seeding		40

Pro - Seeding slightly heavier than normal makes up for the seed that is lost during the ferilizing, raking, and mulching operations. The higher seed rate also accounts for the harsh site, i.e. wind, steep slopes, frost, erosion, etc.

Con - Assuming no loss of seed and successful germination, competition could occur for moisture.

8. Fertilization on Vail Pass is as follows:

Nitrogen (available) 50 lbs/acre

Super phosphate 100 lbs/acre

Fertilizer is applied with the seed and the two are raked in together. A maintenance fertilizer schedule as a follow-up would be ideal for the next 2-3 years. Contracts, however, are let for a specific section of highway construction only and do not carry over for such things as maintenance fertilizer.

9. Commercial sodding in a critical fill area immediately adjacent to the stream was done last fall after the growing season was over.

Pro - This provides immediate protection against erosion when no alternative existed.

Con - Watering is necessary and cost is an obvious consideration ($9,000+/acre). Visual effect may initially be unacceptable. Perhaps a sod of a more "native" nature could be provided at commercial sod farms if lead time for a particular project was sufficient. Some discussion has occurred on using native sod which might be found in the field near the construction area. Realizing it may be mixed slightly in the removal, a chance of success still might exist. Another alternative would be to alternate horizontal rows of commercial sod with rows of standard seeding. This would break up the golf green appearance, allow more mileage out of the sod, and still provide desired erosion control.

10. Mulch and soil retention blanket (jute mesh) are used on all disturbed areas on Vail Pass. Straw 1-2 inches in thickness (1 1/2 tons/acre) is used for mulch and held in place by the jute mesh. The jute used is yarn-like weave approximately 3/16" in diameter and the squares are about 3/4" in dimension.

Other material such as nylon mesh or cellulos could be used to hold the mulch in place but the jute has proven beneficial in other aspects.

Pro - Laying the jute in the bottom of diversion ditches has retarded velocity of flows, prevented scouring of ditches, and trapped sediment. It also prevents rilling from surface runoff and from the short high intensity summer showers. The absorptive capacity of the jute retains moisture for prolonged use.

Con - Cost per acre is $5,300. The rolls weigh 90 pounds and must be taken to the top of a slope prior to topsoiling with a small cat. Fire hazard does exist although smolder resistant material is available. Mulch and jute will keep soils cooler in the spring thus slowing down germination.

11. Willows, shrubs, trees, rocks, and stumps can all add to eventual bank stabilization. Willows can be transplanted with a small cat with little effort thus providing some structural strength to wet areas. Shrubs and trees can be transplanted if sites are suitable. Seed or potted seedlings obviously have the greatest success ratio. The following forbs are planted on a spot basis:

Common Name	Botanical Name	Ounces Pls/acre
Hooker evening primrose	*Oenothera hookeri*	1/2
Penstemon	*Penstemon* spp., *mixed*	1/2
Rockymountain fringed gentian	*Gentiana thermalis*	1/4
Rockymountain iris	*Iris missouriensis*	1/2
Lewis flax	*Linum lewisii*	1/2
Columbine	*Aquilegia* spp.	1/4
Fleabane	*Erigeron* spp.	1/4
Composits	*Compositae* family	3/4
	Total pounds/acre forbs	3 1/2

Large rock placement, old logs or stumps as typical in the old burned and cutover areas on Vail Pass can offer miniture micro-climates preserving soil moisture and adding visual variety to the landscape.

12. Irrigation on Vail Pass is a feast or famine situation. During spring runoff soils are saturated and all efforts to control water movement must be used. A farmer, experienced in irrigation, with hip boots and a shovel during spring runoff is invaluable while revegetation is being established. The "spring irrigator" can check a water flow coming out of a cut bank and at least keep it controlled in one area. Water bars and ditches can be monitored for ice jams.

Once summer comes there is a lack of moisture. Seed will not germinate until a sufficient rainstorm occurs. Due to the short growing season and the need to have vegetation to protect the slopes one cannot afford to wait for a sufficient summer storm to initiate germination or establish adequate root systems. The Highway Department has experimented with watering seeded slopes on Vail Pass as a method of achieving faster growth during the summer season. The small amount of moisture put on the slopes by this method may wet an area enough to maximize moisture benefits from the short summer storm.

13. Sand applied to high mountain roads may prove to be a real problem especially with a four-lane highway in a heavy snow country. The Highway Department reports that annually 660 tons of sanding material/mile were applied to the old Highway 6 over Vail Pass. Twenty-five tons of salt/mile annually are used with the sanding material to keep it from freezing. Accumulation of this material over a period of years literally will snuff out

roadbank revegetation which is just establishing. The problem seems significant above the 10,000 foot level where more sand is used and the growing season is shortest. Last year the Highway Department was able to reclaim approximately 1/3 of the sanding material from I-70 near Straight Creek. Perhaps improved methods and techniques will someday increase the recovery rate even more.

CONCLUSION

This report has listed only a few of the methods used on Vail Pass which relate to revegetation and stabilization. Individuals working in the field of high altitude revegetation should not limit themselves to the few known established techniques. Ingenuity applied to the uniqueness of a project along with a background of known facts and concern to do the job right will provide us with a product our generation can be proud of.

SUMMARY OF I-70 OVER VAIL PASS

Revegetation/Stabilization

The cost figures will vary slightly per specific highway segment based on actual contract bids. All cost show item "in place."

Topsoil - minimum of 4 inches, removal, storage, placement	$4/yd	$2,130/Acre
Grass seed at 40 pounds/acre	$6/lb.	$240/Acre
Fertilizer		$50/Acre
Mulch (straw) at 1 1/2 tons/acre	$150/ton	$225/Acre
Soil retention blanket (jute)	$1.10/sq. yd.	$5,325/Acre
	Total	$7,970/Acre
Forb seed (used in spots) at 3 1/2 lb/ acre	$20/oz.	$1,120/Acre
Sod (commercial) at 22¢/sq. ft.		$9,583/Acre
Lodgepole pine seed at 1/2 lb/acre	$17/lb.	$8/Acre

FOREST SERVICE HIGH-ALTITUDE REVEGETATION

Leonard Hendzel
Rocky Mountain Region
U.S. Forest Service
Lakewood, Colorado

The Forest Service has a great opportunity to conduct revegetation work since it manages most of the alpine and much of the subalpine zone. Since we manage most of these high altitude lands it is a challenge and responsibility to revegetate where needed.

Through the years, our authorized use of the high country by grazing livestock and development like ski areas and roads have resulted in disturbance of the natural vegetative cover. Because of the severity of climate the reestablishment of vegetative cover is particularly difficult in the alpine zone. Successes are few.

I will deal with Forest Service revegetation projects undertaken in the upper reaches of the subalpine and in the alpine throughout the central and northern Rocky Mountains.

Cabin Creek Pilot Project

The first subalpine to alpine revegation effort I worked with was the Cabin Creek Pilot Project on the Gallatin National Forest in southwestern Montana, in the early 1960's. Two nearby areas were included, Carrot Basin at about 9,300 feet, and Cabin Creek at 8,500 to 9,000 feet. The Carrot Basin portion was adjacent to an ARS research area where Fred Gomm conducted revegetation trials a few years earlier.

The purpose of this work was to see if we could reestablish a better vegetative cover on depleted sheep and elk ranges. The site preparation and seeding were by primitive means, since the area was roadless back country, as are most high altitude sheep ranges on the Gallatin Forest. Ground cover averaged only about 40 percent with less palatable forbs, such as tarweed (*Madia glomerata*), groundsel (*Senicio* spp.), and fleabane (*Erigeron* spp.) being dominants. Idaho fescue (*Festuca idahoensis*), mountain brome (*Bromus carinatus*) and oniongrass (*Melica bulbosa*) were the grasses which were a small part of the composition. In a neighboring drainage, which had only received limited use through the years by elk and a few pack and saddle stock, vegetation condition and soil cover were much superior. Grasses, Idaho fescue and tufted hairgrass (*Deschampsia caespitosa*) were dominants in vegetative composition.

Initial treatment of the Cabin Creek project area was reduction of weedy competition by helicopter application of 2,4-D. Rate of application was 2 and 4 pounds acid equivalent per acre. Time of application was early July when we judged forbs to be in their most active growth phase. Further preparation was ground scarification with an on-site improvised spike-toothed harrow pulled by a horse. Next, seeding and fertilization were done by cyclone seeder. Seeding rate was about 15 pounds per acre. High nitrogen content fertilizer was applied at the rate of 100 pounds per acre, with some of the seeding sites receiving no fertilization. Seed was then covered, more or less, with the same harrow. Species planted were smooth brome (*Bromus inermis*), slender wheatgrass (*Agropyron trachycaulum*), Kentucky bluegrass (*Poa pratensis*) and meadow foxtail (*Alopecurus pratensis*).

Based on two years of follow-up studies and observations, the project was judged a failure for the following reasons:

1. The target forbs were not at their maximum growth peak, and many resprouted later that summer or the following year, especially those treated with 2 pounds acid equivalent. Groundsel and yarrow (*Achillea millefolium*) were little affected.

2. The seedbed preparation was not sufficient, nor was the seed covering.

3. Seeding was done too early in the summer, and many of the sprouts died of late summer drought.

The only planted species which were somewhat successful were smooth brome and slender wheatgrass, which were observed on the project area 10 years later. At that elevation, they continued to maintain themselves, but smooth brome did not produce viable seed.

Oniongrass (*Melica bulbosa*) responded best to reduced forb competition resulting from herbicide application.

Lazyman Hill High Altitude Nursery and Monument Hill Watershed Improvement Project

Both of these works were on top of the Gravelly Range, Beaverhead National Forest, in southwestern Montana.

Lazyman Nursery was a Forest Service Research Project at 9,350 feet elevation. Native dominants were Idaho fescue, bearded wheatgrass (*Agropyron subsecundum*), slender wheatgrass, mountain brome, mountain bluegrasses (*Poa* spp.), granddad's whiskers (*Ceum ciliatum*), and cinquefoil (*Potentilla* spp.).

The soils were considered fertile with a high organic matter content and high water-holding capacity. Estimated precipitation was 20 inches, which 25 years later proved to be a poor guess, and it actually was nearer 40 inches.

The site preparation consisted of horse plowing in 1940, disking and floating in 1941. Forty grasses were seeded in early July of 1942. Seed was from low elevation sources except for on-site collected mountain brome. Data was collected over a 10-year period on stand establishment, stand density, reproduction, and longevity.

The following species of grasses maintained or increased over the 10-year period: smooth brome, meadow foxtail, meadow brome (*Bromus erectus*), Kentucky bluegrass, and bearded, slender, and violet wheatgrasses.

A second grouping of planted grasses were those which maintained themselves reasonably well through 9 years, but had a rapid decline in the tenth year. They were: hard fescue (*Festuca ovina duriuscula*), fairway crested wheatgrass (*Agropyron cristatum*), thickspike wheatgrass (*Agropyron dasystachyum*), red fescue (*Festuca rubra*), Russian wildrye (*Elymus junceus*), and mountain brome. Some of the more common indigenous species which failed within 3 years were: rough fescue (*Festuca scabrella*), Idaho fescue, bluebunch wheatgrass (*Agropyron spicatum*), and big bluegrass (*Poa ampla*).

The varieties of smooth brome, meadow brome, and meadow foxtail gave the best overall performance. Meadow foxtail was the only grass known to positively reproduce by seed and was still a vigorous producer after 20 years.

On the basis of Lazyman Nursery research, additional trials were conducted a few miles away in the Geyser Cones area at 9,500 feet. Sheep bedgrounds, dusting beds, and snowbank areas were worked on. Treatment was a good seedbed preparation, terracing, drilling, and covering some portions with straw mulch. Smooth brome and meadow foxtail responded well when fertilized and mulched.

The Monument Hill Watershed Improvement Project was done in the middle 1960's. It was at about the same elevation as the Lazyman Nursery and 8 miles south. The site was first terraced with a small dozer, then seeded and fertilized with cyclone seeders. Meadow foxtail and smooth brome were broadcast at a rate of 6 pounds per acre each. Ten years after, the stand is still well established on the better soils.

East Boulder Plateau Minearal Exploration Rehabilitation

This activity is in the Absaroka Range on the Gallatin Forest. Mineral exploration via core drilling is still active. Elevation is 9,000 to 9,500 feet at the lower reaches of the alpine tundra.

Site preparation includes reshaping drilling sites to the natural land contours. The seed and fertilizer are then distributed by cyclone seeder and covered with rakes. Fertilizer is 10-25-0, applied at a rate of 50 pounds per acre. Earlier rates of 200 pounds per acre resulted in much seedling burning.

Seed Mixture	Pounds Per Acre	Results
Hard fescue	4	Fair
Chewings fescue (*Festuca commutata*)	4	Fair
Meadow foxtail	6	Good
Kentucky bluegrass	4	Fair to poor
Dutch-white clover (Trifolium repens)	2	Poor
Total	20	

Smooth brome was one of the species tried originally, but did very poorly.

The final treatment was placement of brush, treetops, and logs over the plantings. This has been highly beneficial in stand establishment by reducing high intensity sunlight, cutting down wind dessication, and allowing snow to accumulate on this wind-swept tundra.

Planting plugs of native vegetation containing sedges (*Carex* spp.) and tufted hairgrass has been tried on a limited basis.

On very harsh sites in the subalpine at 8,000 feet elevation, they are having good success with thickspike wheatgrass, Sherman bluegrass, and Regar variety of smooth brome. Site treatment and seeding rates were the same as on the alpine site. Thickspike wheatgrass performs the best with harvestable stands produced.

Colorado High-Altitude Revegetation

Most of the high altitude seed trials and reseeding in Colorado has been in the subalpine zone. Where competition has been reduced and terrain is favorable for drilling, success has been high. Some of the more commonly used grasses are smooth brome, timothy (*Phleum pratense*), intermediate wheatgrass (*Agropyron intermedium*), and meadow foxtail. Good short-lived fillers are ryegrass (Lolium perenne), slender wheatgrass, and meadow fescue (Festuca pratensis).

A different method of disturbed site revegetation has been sod replacement on the Rollins Pass Pipeline Project. Keeping the turf moist and reshaping to the natural contour were two important procedures which greatly affected the success of the revegetation.

Ski trails in the alpine and subalpine zones continue to be successfully revegetated. This work has been done on slopes up to 67 percent, the maximum ski terrain. Most of the work (seedbed preparation, seeding, fertilizing and covering) must necessarily be done by hand. Straw or hay mulching is a key to success.

Mont Lewis made observations in the high Uintas of Utah. John Thilenius recently completed a long-term study in the Absarokas of Wyoming. Additional alpine research and application of their observations will aid us in high-altitude revegetation.

SUMMARY

1. Limited work has been done in both Forest Service research and administrative branches, which has resulted in mostly successful reestablishment of vegetative cover on depleted subalpine sites. Past overgrazing or unmanaged grazing has been a major cause of erosion problems and the need for revegetation in the alpine. Very little alpine revegetation has been successful.

2. Smooth brome and meadow foxtail have been the best species for high-altitude revegetation.

3. Additional research is needed into high-altitude solar radiation and wind effects, as well as the use of on-site turf replacement.

BIBLIOGRAPHY

Gomm, F. B. 1962. Reseeding Studies at a Small High Altitude Park in Southwestern Montana. Montana Agr. Exp. Sta. Bull. 568.

Lewis, M. L. 1970. Alpine Rangelands of the Uinta Mountains. USDA, Forest Service, Region 4, Ogden, Utah.

McGinnies, W. J., D. F. Hervey, J. A. Downs, and A. C. Everson. 1963. A Summary of Range Grass Seeding Trials in Colorado. Tech. Bull. 73, Agr. Exp. Sta., Colorado State University.

Marr, John W., David L. Bucker, and David L. Johnson. 1974. Ecological Modification of Alpine Tundra by Pipeline Construction. IN The Proceedings of a Workshop on Revegetation of High Altitude Disturbed Lands, Information Series No. 10, Colorado State University.

Morris, Melvin S. 1961. Unpublished paper, An Ecological Evaluation of the Nonforested Areas in the Subalpine Zone of Cabin Creek, Tepee Creek and Carrot Basin on the Gallatin National Forest.

Thilenius, John F. 1975. Alpine Range Management in the Western United States. Forest Service Res. Pap. RM-157.

A Report on
Group Work Session Number 1

ECOLOGICAL AND CLIMATIC BASE

Richard Ward and Frank Moore

An open and lively discussion followed a brief introduction to the focus of the Work Session. The possibility existed of some overlap with the other two Work Sessions, but it was decided not to limit the comments but to take advantage of the free range of ideas and questions.

A principal concern expressed was the present and projected availability of plant materials, especially seed of colonizers and effective establishment materials of shrubby browse species. In response to the question of why aren't materials available, the reality of the 'supply-demand' process was mentioned. There is as yet no adequate, continuous demand which would justify heavy commercial investments by private seed companies and nurseries. The State Forest Service is considered to be a primary source for tree seedlings, but has only a small involvement in shrub production. The projection of a considerable growth in mining operations at high elevations, with the potential for a large number of small disturbances, was thought likely to bring about the continuous demand needed for more commercial production. More materials than generally realized are available at present, and one function for the Committee might be to periodically assemble the lists of suppliers, including suitability for certain locations.

As is often the case in meetings with similar topics, the most controversial discussion centered around native and introduced materials. Evidence of useful stabilization by introduced species followed by successional invasion by native species was cited, but contrary evidence of exotic monocultures not moving toward a diverse community was also reported. The ecological value of diversity even at the colonizing stage was suggested, as was the significance of utilizing materials which have co-evolved their niche patterns. The virtual absence of comprehensive autecological information on the principal species was mentioned as an important deficit in developing a program of revegetation.

Recognition of different objectives for different parcels of land was supported, as was the need for clearly identifying each objective if a meaningful plan for achieving "success" is to be drawn up. Regarding the success of a revegetation effort, the need for some type of "Index of Rehabilitation" related to various objectives was expressed.

On the matter of base climatic information, it was recognized that there is a considerable amount of existing information, but serious question exists as to its transferability and its relevance to specific sites. Perhaps more important than general trends is a better understanding of the probability that some environmental extreme would wipe out the apparent success of several years. Information on failures should be of particular benefit to revegetation efforts in general. Monitoring of climatic information on the basis of where the problems will be was encouraged. Strongly advocated was the development of a plan for shared information about equipment lists, including sources, costs, what works well and what doesn't.

A Report on
Group Work Session Number 2

PLANT MATERIALS

Dr. Robin L. Cuany
Department of Agronomy
Colorado State University
Fort Collins, Colorado

There were several aspects of plant materials development raised in the discussion by various speakers. Although the arguments were at some times circular i.e., returning again and again to the same themes, I will try and present the discussion by topics.

NITROGEN FIXATION

The most important nitrogen-fixing system is the legume-Rhizobrium association between plant and bacterium. In developing seed sources of native legumes, there is a problem because of irregular seed set and frequent insect infestation of the seeds in the pod. Frequent trips may be necessary to catch ripe seed before it is scattered. Transplanting is difficult unless done in a dormant stage. Finding plants in early spring may be impossible at high altitudes because of snow cover - this leaves fall digging of crowns as about the only possible collection method. If seed is collected, it should be fumigated at the collection site and a soil sample should be gathered to have a source of the appropriate inoculum.

In projecting research on the legume-Rhizobrium system, it will be necessary to consult some of the experts in the accelerating field among whom are:

Forster Davidson, Research Seeds, Inc., St. Joseph, MO;
Harold Evans, Oregon State University, Corvallis, OR;
Lloyd Frederick, USAID, State Department, Washington, D.C.;
Robert Miller, Ohio State University, Columbus, OH;
Lynn Porter, USDA-ARS, Federal Bldg., Fort Collins, CO;
Deane Weber, USDA-ARS, Beltsville, MD;
Richard Weaver, Texas A&M University, College Station, TX.

Some of the above are working on more agricultural-type crops.

Other N_2-fixing systems are being found, and the Utah group (Plummer) report nodules on desert bitterbrush (*Purshia glandulosa*) and also on the accompanying cliffrose. Bacteria could be isolated from these nodules and they are benefitting the plants around them (grasses, etc.) to greener growth on quite "sterile" soils. These nodules are seasonal; similar ones are found on Ceanothus which seem to benefit Ponderosa pine growing with it. For a long time alders have been known to have large nodules. Some grasses, although not nodulated, have been found to contain Spirillum or other bacteria. Meadow foxtail (Alopecurus) in Russia is one of these grasses, though most work has been on tropical grasses and warmth may be necessary to the successful fixation.

The association with fungi, called mycorrhiza, is not known to fix nitrogen but may be important for mineral absorption in shrubs, forbs, and grasses, as well as trees. There are two types, the sheathing type and the VA or endo-mycorrhiza type. The inoculum for these is not usually present except in topsoil and even there it can be killed by greenhouse soil treatment. Foresters bring duff from the forest and work it into their nursery soils. Too much mineral fertilizer may hinder the making of a mycorrhizal association, but a modest level is helpful. Where would the inoculum come from if you have to revegetate a soil which is not a topsoil? Experts in this area for mycorrhiza include:

Martha Christensen; Botany, University of Wyoming, Laramie, WY;
Brent Reeves, Botany and Plant Pathology, CSU, Fort Collins, CO;
C.P.P.(Pat) Reid, Forest and Wood Science, CSU, Fort Collins, CO.

ECOLOGICAL ADAPTATION

Is it possible that a most successful method of revegetation would be to take a mixture of seed, duff (litter), and the microbial and fungal inoculum in it, and mix with water for hydromulching? Such a method has been used at Colstrip, MT, and Ron Sauer was quite emphatic that only in this way is the proper ecological balance maintained. A vigorous discussion followed on the theme of native versus introduced plants and on the related theme of how much plant breeding selection should go into either group. For ecological reasons diversity is important, and ecologists were afraid that plant breeders tended to produce too "narrow" a type. On the other hand, Ericson pointed out the importance of being able to produce seed of the chosen species, with some safeguards to avoid getting too early-seeding strains and instead to keep some of the diversity needed. There is no need to keep the worst strains for persistence, vigor, etc., provided the strains being produced are tested in the problem areas. Some ecotypes are known to have a wide enough adaptation that they will do well, better than the strains of the same species found on the site. Obviously it is more expedient to multiply such strains than to have small lots of a myriad of local strains. If they are selected for seed size they may well be better revegetation materials than anything native to the site and they do not necessarily prevent the invasion, during successional stages, by more local materials. This has been found in the papers by Ray Brown at this workshop and in experience of Dean Kerkling at Vail.

John Ericson is collecting many strains of alpine timothy (e.g. on top of Grand Mesa) and will bulk them together as a wide-base geomplasm. Robin Cuany is doing similar studies on western wheatgrass and hopes soon to tackle tufted hairgrass and the lupines. Continued discussion among Ericson, Ferchau, Hassell, Plummer, Sauer and the chairman was culminated with a very useful suggestion by Rutter of Keystone International that small seed-production plots be raised on ski slopes and similar high altitude areas, to provide some isolation and the right climate to avoid unwanted selection changes (genetic drift).

SHRUB ESTABLISHMENT

A bigger problem than choice of plant material seems to be modifying the microclimate so as to be able to get the shrubs going (whether from seed or transplants). Junipers could be set into rocky breaks of ski areas, and micro-windbreaks could be made in the shaping of tailing piles. In other areas, tree stumps and piles of brush have been useful.

SPECIES SUGGESTIONS

At the close of the group discussion time, four suggestions were made for useful "cover" species:

Gooseberry (*Ribes montigonum*) - good on Wasatch Plateau;
Dwarf horsemint (*Monardella odoratissima*) - a mat-forming ground cover forb;
Wild raspberry (*Rubus deliciosus*) - has obvious advantages;
Mountain rose (*Rosa woodsii*) - attractive as well as tough.

Wendell Hassell (SCS) promised to make available a copy of the list of species for which accessions are being sought, to create the working collection of the new Environmental Plant Center at Meeker. Since this "want list" is a good check list for all of us in revegetation work, as well as being an indication of where we can all help, the chairman of this group recommended it should be printed in these workshop proceedings. It follows this discussion summary.

Appendix

UPPER COLORADO ENVIRONMENTAL PLANT CENTER
NATIVE PLANT COLLECTION LIST
1976

WOODY PLANTS

BOTANICAL NAME	COMMON NAME
Acer glabrum	Rocky Mt. maple
Acer grandidentatum	Bigtooth maple
Amelanchier sp.	Serviceberry
Amorpha sp.	Amorpha, false indigo
Arctostaphylos sp.	Manzanita, bearberry
Artemisia sp.	Sagebrush
Atriplex sp.	Saltbush
Berberis sp.	Barberry, mahonia
Ceanothus sp.	Ceanothus
Cercocarpus sp.	Mountain-mahogany
Chrysothamnus sp.	Rabbitbrush
Clematis sp.	Virgin's bower
Cornus sp.	Dogwood
Cowania sp.	Cliffrose
Crataegus sp.	Hawthorn
Elaegnus commutata	Silverberry
Ephedra sp.	Ephedra, Mormon-tea
Eurotia lanata (ceratoides)	Winterfat
Fallugia paradoxa	Apache-plume
Fendlera rupicola	Fendler bush
Grayia sp.	Hopsage
Holodiscus sp.	Rockspirea
Jamesia americana	Cliffbush
Linnaea borealis	Twinflower
Lonicera sp.	Honeysuckle
Parthenocissus inserta (vitacia)	Creeper or Virginia creeper
Peraphyllum tamosissimum	Squawapple
Philadelphus microphyllus	Mockorange
Physocarpus sp.	Ninebark
Potentilla fruticosa	Cinquefoil
Purshia tridentata	Antelope bitterbrush
Rhamnus sp.	Buckthorn
Rhus sp.	Sumac
Ribes sp.	Currant, gooseberry
Robinia neomexicana	Locust
Sambucus sp.	Elderberry
Shepherdia sp.	Buffaloberry
Sorbus scopulina	Mountain ash
Spiraea caespitosa	Spiraea
Symphoricarpos sp.	Snowberry

WOODY PLANTS (Continued)

BOTANICAL NAME	COMMON NAME
Tetradymia sp.	Horsebrush
Vaccinium myrtillus	Blueberry, whortleberry
Viburnum pauciflorum	Viburnum

FORBS

Achillea lanulosa	Western yarrow
Aquilegia sp.	Columbine
Argemone sp.	Pricklepoppy
Aster sp.	Aster
Astragalus sp.	Milkvetch
Balsamorhiza sp.	Balsamroot
Calochortus sp.	Sego lily, mariposa
Castilleja sp.	Indian paintbrush, painted cup
Chrysopsis sp.	Golden aster
Crepis acuminata	Tapertip hawksbeard
Dryas octopetala	Mountain avens
Epilobium angustifolium	Willowweed, fireweed
Erigeron sp.	Daisy, fleabane
Eriogonum sp.	Wild buckwheat, umbrella plant
Erysimum asperum	Western wallflower
Gaillardia sp.	Blanket flower
Geranium sp. (Perennials high elv.)	Geranium
Gilia sp. (Ipomopsis)	Gilia
Haplopappus sp.	Goldenweed
Hedysarum sp.	Sweetvetch
Helianthus sp.	Sunflower
Hymenoxys sp.	Rubberweed
Kochia americana	Summer-Cypress
Lathyrus sp.	Peavine
Ligusticum potieri	Lovage, loveroot
Linum lewisii	Lewis flax
Lomatium nuttallii	Biscuitroot
Lotus sp.	Trefoil, deervetch
Lupinus sp.	Lupine
Mertensia ciliata	Mountain bluebells
Oenothera sp.	Evening primrose
Oxyria digyna	Mountain sorrel

FORBS (Continued)

BOTANICAL NAME	COMMON NAME
Penstemon sp.	Penstemon, beardtongue
Petalostemon sp.	Prairie clover
Phlox caespitosa	Tufted phlox
Psoralea sp.	Scurfpea
Senecio sp. (Perennials)	Groundsel
Solidago petradoria	Rock goldenrod
Sphaeralcea sp.	Globemallow
Thermopsis sp.	Goldenpea
Trifolium sp. (natives only)	Clover
Verbena sp.	Verbena
Vicia sp.	Vetch
Viguiera multiflora	Goldeneye
Wyethia sp.	Mules-Ears

GRASSES

Agropyron (all species)	Wheatgrass
Bromus anomalus	Nodding brome
Bromus ciliatus	Fringed brome
Bromus marginatus	Mountain brome
Danthonia parryi	Parry oatgrass
Distichlis stricta	Saltgrass
Deschampsia caespitosa	Tufted hairgrass
Elymus (all species)	Wildrye
Festuca arizonica	Arizona fescue
Festuca idahoensis	Idaho fescue
Festuca ovina	Sheep fescue
Festuca thurberi	Thurber fescue
Hilaria jamesii	Galleta
Koeleria cristata	Junegrass
Oryzopsis hymenoides	Indian ricegrass
Poa alpina	Alpine bluegrass
Poa fendleriana	Muttongrass
Poa nevadensis	Nevada bluegrass
Poa sandbergii (secunda)	Sandberg bluegrass
Puccinellia airoides	Alkaligrass
Sitanion hystrix	Squirrel tail
Sporobolus airoides	Alkali sacaton
Sporobolus cryptandrus	Sand dropseed
Stipa columbiana	Columbia needlegrass
Stipa comata	Needle-and-thread
Stipa viridula	Green needlegrass

Botanical and common names checked against Nickerson, Brink, and Feddema (1976) USDA Forest Service Gen. Tech. Rept. RM-20.

A Report on
Group Work Session Number 3

ESTABLISHMENT METHODS WORK GROUP SUMMARY

William J. McGinnies
Crops Research Laboratory
Agricultural Research Service, USDA

The chairman presented a brief report on the Fourteenth Annual Vegetative Rehabilitation and Equipment Workshop held in Omaha February 15 and 16, 1976. Participants who attended the previous High-Altitude Revegetation Workshop had received a copy of "History Range Seeding Equipment Committee 1946-1973." Copies of this publication were given to workshop participants who had not previously received one.

R. V. Adolphson (U.S. Forest Service, Denver) reported on development work being undertaken under the leadership of L. R. Spink (U.S.F.S.) in cooperation with other state and federal agencies to develop steep slope revegetation equipment. The development work is being handled by the Forest Service Equipment Development Center. The primary design criteria are for an implement that will prepare a seedbed, seed, and firm the soil on steep slopes (road cuts, in particular) with a "reach" of 50 to 75 feet and for use on slopes up to 1:1. They plan to hold some informal tests before the end of June, 1976, of the most promising equipment that has developed. They then hope to develop an all purpose machine that will have wide application for the stated conditions. The equipment will also be capable of vegetative propagation plantings.

A considerable interest was expressed in use of sod for establishing vegetation on disturbed areas. Michael McQueen reported that some sodding has been done at Winter Park using native sod with generally favorable results. Best results were obtained where the ground was roughened to produce a suitable bed for sodding and where the sod was firmly rolled into this loosened soil. Steve Stephens of Copper Mountain Development reported use of commercial bluegrass sod around base developments, but they found that water needs were high.

It was generally agreed that there is a fair degree of flexibility with regard to the date for laying sod. The main concern is that the temperature is adequate for growth and that the sod material is growing actively. Watering following laying the sod also seems to be essential for really successful establishment.

A major problem related to sodding (and to other vegetative propagation, for that matter) is to find a suitable source of material. Cutting sod destroys the vegetation on the area from which the sod is removed. On a mining operation or a road-building operation, it may be possible to "leap frog" the material from an area about to be disturbed back to an area that has previously been disturbed and prepared for rehabilitation. Jim Gregg of the Holy Cross Ranger District reported that they have successfully used the leap-frog method of sod cutting. Another problem in cutting sod is rock in the soil; even small rocks cause difficulty in operating a sod cutter.

A desire was expressed by several persons to find a grass species suitable for sprigging. This species should be one that will spread rapidly by rhizomes or stolons.

Considerable success was reported in transplanting trees and shrubs. Spruce, willow, aspen, subalpine fir and lodgepole pine have been successfully transplanted at Winter Park. Trees have been transplanted directly after digging, but some have been held for as much as two years after digging by storing in nursery-type conditions using watering and mulching. Survival has been as high as 80%. The greatest success has been obtained using the tree digging and planting machines that dig the tree with the roots and soil intact. A planter with a single, strong heavy blade was reported to be more satisfactory than one with four lighter-weight blades. The four-blade model has been subject to damage in rocky soil.

The key to successful transplanting has been to water the tree at the time it is put in place. Another important factor has been to avoid attempting to plant on dry, wind-swept locations where growth of even established trees is restricted. Digging trees and establishing them in pots to get a good root growth has also been successful, but care must be taken not to over-water trees such as Engleman spruce. Root pruning in the year preceding digging has been tried on a limited scale and results have been encouraging.

Cuttings have been used to establish willow and Populus species with fair to excellent results. However more needs to be known about this technique. North Idaho College has a research program under way to determine the best methods and species for establishment from cuttings.

With the exception of the Highway Department, a high percentage of seeding is done by broadcasting rather than by drilling the seed. A need for a satisfactory broadcaster was mentioned. Most broadcasters lack durability and capacity, and they do not spread mixtures of seed evenly. Covering and/or packing after broadcasting has greatly improved stand establishment. The use of packers was suggested if soil and moisture conditions were satisfactory. Track-packing with a crawler tractor has been used with good success at Winter Park and several other locations. Many "seedbeds" left after grading are not satisfactory for broadcasting. It was suggested that an educational program is needed to get the contractor to leave a roughened seedbed rather than the customary smoothly finished cuts and fills.

A number of persons felt that one of the most important factors in successful establishment was long term planning. The tendency has been for the person to plant an area and then forget it. It was strongly recommended that plans be made and funds set aside for maintenance (or even replanting) in following years. In many cases, fertilizer or cultivation may be needed for several years after planting. Where possible, such items might be included in the original specifications.

Another major problem is that construction contracts usually include the requirement that disturbed areas be revegetated, but that we do not have workable techniques for seeding certain harsh sites and for seeding the alpine in general. A very specific request to find methods for establishing vegetation on road cuts in steep topography in the alpine zone was expressed by Mr. Reed Harris of Morrison-Knudsen Co. Very little revegetation research is being conducted in the alpine zone; most research is in the subalpine and lower elevations.

There was a great deal of participation by the individuals in this discussion group and the Session Chairman apologizes for not getting the names of all who contributed comments and suggestions. From the amount of "head-nodding" observed following many of the comments, I gained the impression that there was general agreement on most points and that many people were having the same general experiences with the various problems of establishment. I want to single out and thank Bob Malmgren, U.S. Forest Service, for taking the detailed notes without which this report could not have been prepared.

LIST OF WORKSHOP PARTICIPANTS

Abbot, Laurence R.
Colorado Division of Highways
P. O. Box 2107
Grand Junction, Colorado 81501

Adolphson, Raymond V.
Division of Engineering
U. S. Forest Service
P. O. Box 25127
Lakewood, Colorado 80225

Alder, G. Michael
Native Plants, Inc.
2842 South West Temple
P. O. Box 15526
Salt Lake City, Utah 84115

Anderson, Jim O.
Mile High Seed Company
P. O. Box 1988
Grand Junction, Colorado 81501

Armbrust, Art
Sharp Brothers Seed Co.
Healy, Kansas 67850

Bailey, Don
Wyoming State Dept. of Envir. Qual.
Land Quality Div.
Cheyenne, Wyoming 82002

Baker, Bert
Division of Wildlife
317 W. Prospect
Fort Collins, Colorado 80521

Bare, Norman H.
1625 S. Fairway Drive
Pocatello, Idaho 83201

Barnes, Tom
1017 Gibbon
Laramie, Wyoming 82070

Barrau, Enrique
Agronomy Department
Colorado State University
Fort Collins, Colorado 80523

Bauer, Ronald F.
U. S. Forest Service
Division of Watershed Management
P. O. Box 25127
Lakewood, Colorado 80225

Beach, Gary G.
Wyoming State Dept. of Envir. Qual.
Land Quality Division
Cheyenne, Wyoming 82002

Beauregard, B. J.
Arapahoe/Roosevelt Natl. Forests
Box 216
Hot Sulphur Springs, Colorado 80451

Berg, W. A.
Agronomy Department
Colorado State University
Fort Collins, Colorado 80523

Bonnickson, David
Breckenridge Ski Corporation
P. O. Box 1058
Breckenridge, Colorado 80424

Bowles, Arthur
Aspen Skiing Corporation
Box 1248
Aspen, Colorado 81611

Borden, Thomas B.
Colorado State Forester
172 RMFRES Bldg.
CSU Campus
Fort Collins, Colorado 80523

Bragonier, Wendell
1100 Ellis
Fort Collins, Colorado 80521

Brink, John M.
U. S. Environmental Protection Agency
1860 Lincoln Street
Denver, Colorado 80203

Brown, James A.
Environmental Control Engineer
Climax Mine
Climax Molybdenum Company (AMAX,Inc.)
Climax, Colorado 80429

Brown, Larry F.
Environmental Control Engineer
Urad-Henderson Mines
Climax Molybdenum Company
(AMAX, Inc.)
Box 68
Empire, Colorado 80438

Brown, Raymond W., Jr.
U. S. Forest Service
Intermountain Forestry Sci. Lab.
860 North 12th East
Logan, Utah 84321

Buckner, David
Department of Biology
University of Colorado
Boulder, Colorado 80302

Butts, David B.
Resource Management Specialist
U. S. National Park Service
Room 3310, Interior Building
13th and C Streets, N.W.
Washington, D.C. 20240

Carnahan, Glenn F.
Manager
Plant Materials Center
SCS - USDA
P. O. Box 1105
Meeker, Colorado 81641

Carper, Anthony
Winter Park Recreation Assoc.
Box 36
Winter Park, Colorado 80482

Cattrell, Edward B.
Associate Professor
Environmental Protection and
Technology Department
Colorado Mountain College
Leadville, Colorado 80461

Chief of Soils Section
Division of Watershed Management
USDA Forest Service
1621 N. Kent Street
Arlington, Virginia 22209

Christie, Forrest R.
Denver Water Department
189 East 109th Avenue
Denver, Colorado 80233

Clark, Rob
Snowmass Ski Corporation
Box 1248
Aspen, Colorado 81611

Coren, Alex L.
Mountain Bell
660 Bannock - Room 175
Denver, Colorado 80204

Crouch, Bill
Winter Park Recreation Association
Winter Park, Colorado 80482

Cuany, Robin L.
Agronomy Department
CSU Campus
Fort Collins, Colorado 80523

Daly, Andy
Copper Mountain
P. O. Box 1
Copper Mountain, Colorado 80443

Davidson, Mrs. Obby
Environmental Engineer
Molycor Inc.
Questa Division
Questa, New Mexico 87556

Eaman, Tom
Soil Conservation Service
P. O. Box 17107
Denver, Colorado 80217

Echols, James W.
Extension Seed Certification
Agronomy Department
CSU Campus
Fort Collins, Colorado 80523

Ekrem, Martin
Conwed Corporation
5963 South Krameria Street
Englewood, Colorado 80110

Ellingson, H. G.
McCall-Ellingson
and Morrill, Inc.
1721 High Street
Denver, Colorado 80218

Ericson, John
Mile High Seed Company
P. O. Box 1988
Grand Junction, Colorado 81501

Evans, Dr. Chester E.
Area Director USDA-ARS
Box E, Federal Bldg.
Fort Collins, Colorado 80522

Ferchau, Hugo A.
Western State College
Gunnison, Colorado 81230

Ferguson, James T.
Climax Molybdenum Company
13949 W. Colfax Avenue
Golden, Colorado 80401

Feucht, James R.
Horticulturist
CSU Extension
909 York Street
Denver, Colorado 80303

Friedenberger, Frank
Arkansas Valley Seeds, Inc.
P. O. Box 270
Rocky Ford, Colorado 81067

Fullerton, Bob
Johns-Manville
1015 Broadwater
Billings, Montana 59107

George, Randal
Lake Eldora Corporation
Box 438
Nederland, Colorado 80466

Goodman, Patsy
Environmental Division
Colorado Highway Department
4200 East Arkansas Avenue
Denver, Colorado 80222

Gordon, Roger R.
Greater Shoshone County, Inc.
Box 768
Osburn, Idaho 83849

Gregg, Jim
U. S. Forest Service
P. O. Box 0
Minturn, Colorado 81645

Harris, Reed
Morrison Knudson Company
P. O. Box 98
Carbondale, Colorado 81623

Harthill, Michal Ann
Denver Mining Research Center
U. S. Bureau of Mines
Building 20, Denver Federal Center
Denver, Colorado 80225

Hassell, Wendell G.
Plant Materials Specialist
USDA Soil Conservation Service
P. O. Box 17107
Denver, Colorado 80217

Havig, Dennis
U. S. Forest SErvice
P. O. Box 188
Dillon, Colorado 80435

Hefner, Mark
Colorado Bureau of Mines
1845 Sherman Street
Denver, Colorado 80203

Hendzel, Leonard
U. S. Forest Service,
Range and Wildlife
P. O. Box 25127
Lakewood, Colorado 80225

Hironaka, Min
College of For., Wild., & Range Sci.
University of Idaho
Moscow, Idaho 83843

Hoeft, Darwin
USFS - Medicine Bow N.F.
605 Skyline Drive
Laramie, Wyoming 82070

Hoefer, Phil
Colorado State Forest Service
Foothills Campus
CSU
Fort Collins, Colorado 80523

Howard, Gene S.
USDA-ARS High Plains
Research Station
Route 1, Box 698
Cheyenne, Wyoming 82001

Jackson, Larry
Gold Resources, Inc.
P. O. Box 595
Cripple Creek, Colorado 80813

Jewell, S. R.
AMAX Inc.
4704 Harlan Street
Denver, Colorado 80212

Johnson, Donal D.
Dean, College of Agricultural
Sciences
CSU Campus
Fort Collins, Colorado 80523

Johnson, James G.
Colorado Division of Highways
4200 E. Arkansas Avenue, Room 309
Denver, Colorado 80222

Johnson, Willy
Vail Associates, Inc.
P. O. Box 7
Vail, Colorado 81657

Johnston, Robert S.
USFS - Intermountain Forest and
Range Experiment Station
1361 Maple Drive
Logan, Utah 84321

Jones, Loring M.
Northplan Seed Prod.
1546 Borah Avenue
Moscow, Idaho 83843

Jordan, John Patrick
Director of Experiment Station
CSU Campus
Fort Collins, Colorado 80523

Keammerer, Warren
S & K Associates
2865 Emerson Avenue
Boulder, Colorado 80303

Keim, Dr. Wayne F.
Agronomy Department
Colorado State University
Fort Collins, Colorado 80523

Kelley, Robert D.
USDA White River National Forest
P. O. Box 0
Minturn, Colorado 81645

Kellogg, Gary F.
U. S. Forest Service
Shoshone/Bighorn National Forests
2020 - 12th Street
Cody, Wyoming 82414

Kenny, Stephen
Department of Agronomy
CSU Campus
Fort Collins, Colorado 80523

Kerkling, Dean W.
Vail Associates, Inc.
P. O. Box 7
Vail, Colorado 81657

King, Arnold D.
USDA Soil Conservation Service
P. O. Box 17107
Denver, Colorado 80217

Klco, Kenneth S.
The Flintkote Co.
Box 80
Coaldale, Colorado 81222

Kline, Gary A.
Steamboat LTVRDI
P. O. Box 1178
Steamboat Springs, Colorado 80477

Knipe, Duane
U. S. Forest Service
Rocky Mountain Station
Tempe, Arizona

Laycock, William
USFS - Rocky Mountain Forest and Range Experiment Station
240 W. Prospect
Fort Collins, Colorado 80523

Leonard, Marian
607 W. Second Street
Leadville, Colorado 80461

Ludwig, James J.
Manager of Mines
Climax Molybdenum Company
13949 West Colfax Avenue
Golden, Colorado 80401

Malmgren, Robert C.
Roosevelt and Arapahoe National Forests
U. S. Forest Service
Federal Building
Fort Collins, Colorado 80521

Marbry, James W.
Flatiron Land Management Company
P. O. Box 229
Boulder, Colorado 80302

Marr, John W.
Department of Biology (EPO)
University of Colorado
Boulder, Colorado 80302

Marshall, Thomas
Aspen Skiing Corp.
Box 1248
Aspen, Colorado 81611

Martin, John F.
U. S. Environmental Protection Agency
Extraction Technology Branch
5555 Ridge Avenue
Cincinnati, Ohio 45245

Massa, Philip
Johns-Manville Sales Corp./ Exploration Dept.
1015 Broadwater Avenue, Suite 13
Billings, Montana 59101

Matt, C. Diane
600 Emerson Street
Denver, Colorado 80218

McClave, John
P. O. Box 1677
Breckenridge, Colorado 80424

McGinnies, William J.
USDA-ARS
Crops Research Laboratory
CSU Campus
Fort Collins, Colorado 80523

McKee, Guy W.
Department of Agronomy
Pennsylvania State University
University Park, Pennsylvania 16802

McQueen, Mike
Winter Park Ski Area
Box 13
Winter Park, Colorado 80482

Menning, Edgar
Box 2002 Moraine Route
Rocky Mountain National Park
Estes Park, Colorado 80517

Miller, James E.
Public Service Company of Colorado
550 15th Street
Denver, Colorado 80202

Milstein, Gene and Dee
Applewood Seed Company
833 Parfet Street
Lakewood, Colorado 80215

Moore, Frank D.
Department of Horticulture
Shepardson Hall
CSU
Fort Collins, Colorado 80523

Moritz, Chris G.
Chris G. Moritz, Inc.
495 South Jersey Street
Denver, Colorado 80222

Mosman, Skip James
Winter Park Recreation Assoc.
Box 36
Winter Park, Colorado 80482

Moxley, Mark
2669 Ninth Avenue
Longmont, Colorado 80501

Moyer, Joe
Plant Science Department
University of Wyoming
P. O. Box 3354
Laramie, Wyoming 82070

Murray, Glen
Route 3, Box 177
Brighton, Colorado 80601

Nelson, Dick
Steamboat
P. O. Box 1178
Steamboat Springs, Colorado 80477

Nishimura, John Y.
Division of Watershed Management
U. S. Forest Service
P. O. Box 25107
Lakewood, Colorado 80225

Noonan, Patrick
The Nature Conservancy
1800 N. Kent Street
Arlington, Virginia 22209

Padilla, Walter W.
Agronomy Department
Colorado State University
Fort Collins, Colorado 80523

Pecka, Jeffrey L.
1700 - 17th, Apt. B-9
Boulder, Colorado 80302

Pick, Robert
Colorado Division of Wildlife
6060 Broadway
Denver, Colorado 80216

Pike, Dan
The Nature Conservancy
820 - 16th Street, No. 420
Denver, Colorado 80202

Plummer, A. Perry
U. S. Forest Service
Research Center
Ephraim, Utah 84627

Pommerening, Ed
Revegetation Engineer
The Bunker Hill Company
P. O. Box 29
Kellogg, Idaho 83837

Preston, David
Stearns-Roger, Inc.,
Environmental Service Division
Box 5888
Denver, Colorado 80217

Randall, Rick
Randall and Blake, Inc.
Seeding Contractors
4879 South Windemere
Englewood, Colorado 80110

Rankin, Bob
U. S. Forest Service
806 West Hallam
Aspen, Colorado 81611

Reed, Gary
Lake Eldora Corporation
Box 438
Nederland, Colorado 80466

Reeder, Jean D.
USDA - ARS
Box E
Fort Collins, Colorado 80522

Regelin, Wayne
Rocky Mountain Forest and
Range Experimental Station
240 West Prospect Street
Fort Collins, Colorado 80523

Rindahl, Gilbert F.
Director
Reclamation Division
Department of Natural Resources
103 Columbine Building
1845 Sherman Street
Denver, Colorado 80203

Ronco, Dr. Frank
Silviculturist
Rocky Mountain Forest and
Range Experimental Station
240 W. Prospect Street
Fort Collins, Colorado 80523

Rutter, John W.
Keystone International
P. O. Box 38
Keystone, Colorado 80435

Sako, Jerry
28054 Way Admiral Trail
Evergreen, Colorado 80439

Sauer, Ronald H.
Battelle Northwest Labs
Richland, Washington 99352

Savage, Melissa
Grassland Resources
P. O. Box 1211
Santa Fe, New Mexico 87501

Schachterle, Dean M.
U. S. Bureau of Reclamation
6030 Lewis Street
Arvada, Colorado 80004

Schnepf, Max
Editor
Soil Conservation Society of
America
7515 NE Ankeny Road
Ankeny, Iowa 50021

Sedgley, Ellis
State Rs. Conservationist
Soil Conservation Service
P. O. Box 17107
Denver, Colorado 80217

Sherman, Harris
Executive Director
Department of Natural Resources
103 Columbine Building
1845 Sherman Street
Denver, Colorado 80203

Sims, Jon A.
Wyoming Highway Department
P. O. Box 1708
Cheyenne, Wyoming 82001

Sims, Dr. Phillip L.
Range Science Department
Colorado State University
Fort Collins, Colorado 80523

Slater, J. Robert
Bureau of Reclamation
P. O. Box 507
Cheyenne, Wyoming 82001

Smith, Graeme
Tussock Grasslands Institute
Lincoln College
Christchurch, New Zealand

Smith, Tom Wiley
Colorado Division of Highways
4200 E. Arkansas Street
Denver, Colorado 80222

Snobble, J. B.
Aspen Skiing Corporation
Aspen, Colorado 81611

Stadler, Carl
Johns-Manville Corporation
1015 Broadwater Avenue, Suite 13
Billings, Montana 59102

Stephens, Steve
Copper Mountain Ski Area
P. O. Box 1
Copper Mountain, Colorado 80443

Stevens, David
Rocky Mountain National Park
Estes Park, Colorado 80517

Stevenson, Karen
10585 West 23rd Place
Lakewood, Colorado 80215

Stewart, William G.
Agronomy Department
Colorado State University
Fort Collins, Colorado 80523

Stienmier, Harold
Consulting Engineer
1318 McKinley
Canon City, Colorado 81212

Strachan, Marvin D.
Colorado State Forest Service
Foothills Nursery, CSU
Fort Collins, Colorado 80523

Suhr, David O.
ASARCO, Inc.
801 Spruce Street
Box 936
Leadville, Colorado 80461

Swanson, Bert
Department of Horticulture
Shepardson Hall, CSU
Fort Collins, Colorado 80523

Taliaferro, Rex
Colorado Division of Wildlife
6060 Broadway
Denver, Colorado 80216

Thatcher, Jeff
Homestake Mining Company
P. O. Box 397
Gunnison, Colorado 81230

Thilenius, John
Rocky Mountain Forest and
Range Experiment Station
U. S. Forest Service
P. O. Box 3313
University Station
Laramie, Wyoming 82071

Timmins, Tom
Breckenridge Ski Corporation
P. O. Box 1058
Breckenridge, Colorado 80424

Thirgood, Dr. J. V.
Editor, Reclamation Review
University of British Columbia
Faculty of Forestry
Vancouver, B.C., Canada

Todd, Jeff
AMAX Environmental Service
4704 Harlan Street
Denver, Colorado 80212

Todd, Stan
Johns' Manville Corporation
1015 Broadwater, Suite 13
Billings, Montana 59102

Tooker, Thomas M.
Graduate Student
University of Northern Colorado
Greeley, Colorado 80631

Townsend, C. E.
Crops Research Center
USDA - ARS
Colorado State University
Fort Collins, Colorado 80523

Tupa, Mike
Environmental Division
Colorado Highway Department
4200 East Arkansas Avenue
Denver, Colorado 80222

Vader, Robert
U. S. Bureau of Reclamation
841 S. Jellison Court
Denver, Colorado 80226

Vogelmann, H. W.
Botany Department
University of Vermont
Burlington, Vermont 05401

Ward, R. T.
Botany Department
Colorado State University
Fort Collins, Colorado 80523

Wegrzyn, Victor
Department of Agronomy
Colorado State University
Fort Collins, Colorado 80523

Wilderman, Paul
Winter Park Recreational Assoc.
Box 36
Winter Park, Colorado 80482

Willard, Dr. Beatrice
President's Council on
  Environmental Quality
722 Jackson Place, NW
Washington, D. C. 20006

Williams, Clifford
State Resource Conservationist
USDA - SCS
P. O. Box 648
Temple, Texas 76501

Williams, Lynn L.
U. S. Forest Service
605 Skyline Drive
Laramie, Wyoming 82070

Young, Bennett H.
Federal Energy Administration
1075 S. Yukon Court
Denver, Colorado 80226

Young, Don
Colorado State Forest Service
912 Rudd Avenue
Canon City, Colorado 81212

Young, Linda
Colorado Mountain College
E. Campus
Leadville, Colorado 80461

Zuck, Ronald H.
Range Science Department
Colorado State University
Fort Collins, Colorado 80523

STUDENTS

Grossnickel, Steve
Colorado State University
Fort Collins, Colorado 80523

Hollander, Adele
Colorado State University
Fort Collins, Colorado 80523

Kukachka, Bob
Colorado State University
Fort Collins, Colorado 80523

Mallory, Glenn
Western State College
Gunnison, Colorado

Prchal, Bob
Washington State University
Pullman, Washington

Richardson, Jerry
Colorado State University
Fort Collins, Colorado 80523

Snell, Gregg
Colorado State University
Fort Collins, Colorado 80523

Soester, Lowell
Colorado State University
Fort Collins, Colorado 80523

Williams, Bill
Colorado State University
Fort Collins, Colorado 80523

Williams, Shiela
Colorado State University
Fort Collins, Colorado 80523

The following students represent
Colorado Mountain College,
Leadville, Colorado 80461.

Anderson, Dan
Burnell, Brad
Ebright, Mark
Fronk, Rick
Hartley, Don
Kruger, Merl
Maddock, Tom
Maholona, Chris
Stewart, Harry
Street, Rick
Vaselin, John