PERMIT CHANGE TRACKING FORM

DATE RECEIVED	7/1/93	PERMIT NUMBER	ACT/007/033
Title of Proposal: Vegetative Test Plots		PERMIT CHANGE #	93A
Description:		PERMITTEE	ANDALEX RESOURCES
		MINE NAME	WILDCAT LOADOUT

	DATE DUE	DATE DONE	RESULT	
☐ **15 DAY INITIAL RESPONSE TO PERMIT CHANGE APPLICATION**		---	☒ ACCEPTED	☐ REJECTED
☐ Notice of Review Status of proposed permit change sent to the Permittee.		8/4/93	**Permit Change Classification**	
☐ Request additional review copies prior to Division/Other Agency review.			☐ Significant Permit Revision	
☐ Notice of Approval of Publication. (If change is a Significant Revision.)			☐ Permit Amendment	
☐ Notice of request to modify proposed permit change prior to approval.			☐ Incidental Boundary Change	

REVIEW TRACKING	INITIAL REVIEW		MODIFIED REVIEW		FINAL REVIEW AND FINDINGS	
DOGM REVIEWER	**DUE**	**DONE**	**DUE**	**DONE**	**DUE**	**DONE**
☐ Administrative _____						
☐ Biology _____						
☐ Engineering _____						
☐ Geology _____						
☐ Soils _____						
☐ Hydrology _____						
☐ Bonding _____						
☐ AVS Check _____						
COORDINATED REVIEWS	**DUE**	**DONE**	**DUE**	**DONE**	**DUE**	**DONE**
☐ OSMRE						
☐ US Forest Service						
☐ Bureau of Land Management						
☐ US Fish and Wildlife Service						
☐ US National Parks Service						
☐ UT Environmental Quality						
☐ UT Water Resources						
☐ UT Water Rights						
☐ UT Wildlife Resources						
☐ UT State History						
☐ Other						

☐ Public Notice/Comment/Hearing Complete (If the permit change is a Significant Revision)		☑ Permit Change Approval Form signed and approved effective as of this date. ☐ Permit Change Denied.	9/29/93
☐ Copies of permit change marked and ready for MRP.		☐ Notice of ☑ Approval ☐ Denial to Permittee.	9/29/93
☐ Special Conditions/Stipulations written for approval.		☑ Copy of Approved Permit Change to File.	9/29/93
☐ TA and CHIA modified as required.		☐ Copy of Approved Permit Change to Permittee.	
☐ Permit Change Approval Form ready for approval.		☐ Copies to Other Agencies and Price Field Office.	

PERMIT CHANGE CHRONOLOGY

Title of Proposal: VEGETATIVE TEST PLOTS	PERMIT NUMBER: ACT/007/033
Description:	PERMIT CHANGE #: 93A
	PERMITTEE: ANDALEX RESOURCES
	MINE NAME: WILDCAT LOADOUT

DATE		DOCUMENT ALL ACTIVITIES ASSOCIATED WITH THIS PERMIT CHANGE
	☐Sent ☒Recv'd.	Initial Application for Permit Change Received from Permittee
	☐Sent ☐Recv'd.	
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☐ ADDITIONAL SHEETS

PERMIT AMENDMENT APPROVAL

Title: VEGETATIVE TEST PLOTS	PERMIT NUMBER: ACT/007/033
Description:	PERMIT CHANGE #: 93A
	MINE: WILDCAT LOADOUT
	PERMITTEE: ANDALEX RESOURCES

WRITTEN FINDINGS FOR PERMIT APPLICATION APPROVAL		YES, NO or N/A
1.	The application is complete and accurate and the applicant has complied with all the requirements of the State Program.	
2.	The proposed permit area is not within an area under study or administrative proceedings under a petition, filed pursuant to R645-103-400 or 30 CFR 769, to have an area designated as unsuitable for coal mining and reclamation operations, unless:	
	A. The applicant has demonstrated that before January 4, 1977, substantial legal and financial commitments were made in relation to the operation covered by the permit application, or	
	B. The applicant has demonstrated that the proposed permit area is not within an area designated as unsuitable for mining pursuant to R645-103-300 and R645-103-400 or 30 CFR 769 or subject to the prohibitions or limitations of R645-103-230.	
3.	For coal mining and reclamation operations where the private mineral estate to be mined has been severed from the private surface estate, the applicant has submitted to the Division the documentation required under R645-301-114.200.	
4.	The Division has made an assessment of the probable cumulative impacts of all anticipated coal mining and reclamation operations on the hydrologic balance in the cumulative impact area and has determined that the proposed operation has been designed to prevent material damage to the hydrologic balance outside the permit area.	
5.	The operation would not affect the continued existence of endangered or threatened species or result in destruction or adverse modification of their critical habitats, as determined under the Endangered Species Act of 1973 (16 U.S.C. 1531 et.seq.).	
6.	The Division has taken into account the effect of the proposed permitting action on properties listed on and eligible for listing on the National Register of Historic Places. This finding may be supported in part by inclusion of appropriate permit conditions or changes in the operation plan protecting historic resources, or a documented decision that the Division has determined that no additional protection measures are necessary.	
7.	The Applicant has demonstrated that reclamation as required by the State Program can be accomplished according to information given in the permit application.	
8.	The Applicant has demonstrated that any existing structure will comply with the applicable performance standards of R645-301 and R645-302.	
9.	The Applicant has paid all reclamation fees from previous and existing coal mining and reclamation operations as required by 30 CFR Part 870.	
10.	The Applicant has satisfied the applicable requirements of R645-302.	
11.	The Applicant has, if applicable, satisfied the requirements for approval of a long-term, intensive agricultural postmining land use, in accordance with the requirements of R645-301-353.400.	

SPECIAL CONDITIONS OR STIPULATIONS TO THE PERMIT AMENDMENT APPROVAL		YES	NO
1.	Are there any variances associated with this permit amendment approval? If yes, attach.		
2.	Are there any special conditions associated with this permit amendment approval? If yes, attach.		
3.	Are there any stipulations associated with this permit amendment approval? If yes, attach.		

The Division hereby grants approval for Permit Amendment to the Existing Permit by incorporation of the proposed changes described herein and effective the date signed below. All other terms and conditions of the Existing Permit shall be maintained and in effect except as superseded by this Permit Amendment.

Signed _____

Director, Division of Oil, Gas and Mining

_____

EFFECTIVE DATE

APPLICATION FOR PERMIT CHANGE

Title of Change:	Permit Number: / /
	Mine:
	Permittee:

Description, include reason for change and timing required to implement:

☐ Yes	☐ No	1. Change in the size of the Permit Area? _____ acres ☐ increase ☐ decrease.
☐ Yes	☐ No	2. Change in the size of the Disturbed Area? _____ acres ☐ increase ☐ decrease.
☐ Yes	☐ No	3. Will permit change include operations outside the Cumulative Hydrologic Impact Area?
☐ Yes	☐ No	4. Will permit change include operations in hydrologic basins other than currently approved?
☐ Yes	☐ No	5. Does permit change result from cancellation, reduction or increase of insurance or reclamation bond?
☐ Yes	☐ No	6. Does permit change require or include public notice publication?
☐ Yes	☐ No	7. Permit change as a result of a Violation? Violation #
☐ Yes	☐ No	8. Permit change as a result of a Division Order? D.O.#
☐ Yes	☐ No	9. Permit change as a result of other laws or regulations? Explain:
☐ Yes	☐ No	10. Does permit change require or include ownership, control, right-of-entry, or compliance information?
☐ Yes	☐ No	11. Does the permit change affect the surface landowner or change the post mining land use?
☐ Yes	☐ No	12. Does permit change require or include collection and reporting of any baseline information?
☐ Yes	☐ No	13. Could the permit change have any effect on wildlife or vegetation outside the current disturbed area?
☐ Yes	☐ No	14. Does permit change require or include soil removal, storage or placement?
☐ Yes	☐ No	15. Does permit change require or include vegetation monitoring, removal or revegetation activities?
☐ Yes	☐ No	16. Does permit change require or include construction, modification, or removal of surface facilities?
☐ Yes	☐ No	17. Does permit change require or include water monitoring, sediment or drainage control measures?
☐ Yes	☐ No	18. Does permit change require or include certified designs, maps, or calculations?
☐ Yes	☐ No	19. Does permit change require or include underground design or mine sequence and timing?
☐ Yes	☐ No	20. Does permit change require or include subsidence control or monitoring?
☐ Yes	☐ No	21. Have reclamation costs for bonding been provided or revised for any change in the reclamation plan?
☐ Yes	☐ No	22. Is permit change within 100 feet of a public road or perennial stream or 500 feet of an occupied dwelling?
☐ Yes	☐ No	23. Is this permit change coal exploration activity ☐ inside ☐ outside of the permit area?

☐ **Attach 3 complete copies of proposed permit change as it would be incorporated into the Mining and Reclamation Plan.**

I hereby certify that I am a responsible official of the applicant and that the information contained in this application is true and correct to the best of my information and belief in all respects with the laws of Utah in reference to commitments, undertakings, and obligations, herein.

_____

Signed - Name - Position - Date

Subscribed and sworn to before me this ____ day of _____, 19 ____.

_____

Notary Public

My Commission Expires: _____, 19____

Attest: STATE OF _____ } ss:

COUNTY OF _____ }

Received by Oil, Gas & Mining

ASSIGNED PERMIT CHANGE NUMBER

Application for Permit Change
Detailed Schedule of Changes to the Permit

Title of Change:	Permit Number: / /
	Mine:
	Permittee:

Provide a detailed listing of all changes to the mining and reclamation plan which will be required as a result of this proposed permit change. Individually list all maps and drawings which are to be added, replaced, or removed from the plan. Include changes of the table of contents, section of the plan, pages, or other information as needed to specifically locate, identify and revise the exiting mining and reclamation plan. **Include page, section and drawing numbers as part of the description.**

			DESCRIPTION OF MAP, TEXT, OR MATERIALS TO BE CHANGED
☐ ADD	☐ REPLACE	☐ REMOVE	
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Any other specific or special instructions required for insertion of this proposal into the Mining and Reclamation Plan?

ACT/007/033 - 93A

4.4 Fish

There are no active fisheries as there are no permanent bodies of water or perennial streams in the area. No aquatic fauna are found.

4.5 Threatened or Endangered Species

There have been no known threatened or endangered species on or near the lease area according to a survey conducted by the Utah Division of Wildlife Resources.

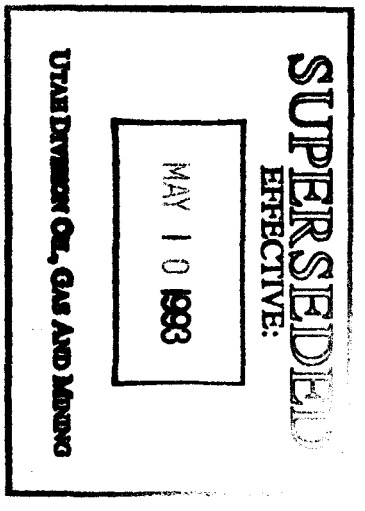
5. Impacts of Operations

Construction of all roads, powerlines, and surface facilities has been completed and loading operations have commenced. Therefore, no additional impact of operations on wildlife is anticipated. Powerlines were constructed according to DWR and USF&W guidelines. It should be noted that this facility has had a good history of co-existing with wildlife in this area. This is constantly observed.

UMC 783.21 Soil Resources Information

I. Soil Survey and Vegetation Inventory (please see Appendix D and Appendix I).

1. Introduction

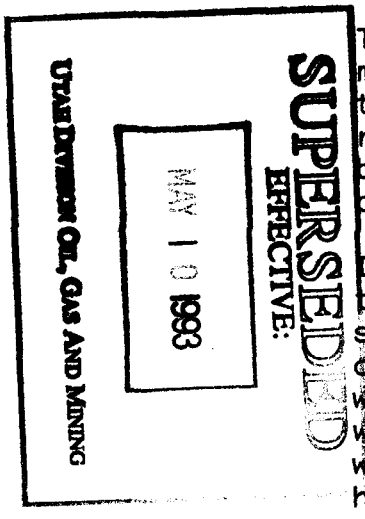


Appendix D is a survey conducted by the SCS in the Wildcat area and depicts the major soil types here. Appendix D also includes a survey including sampling as performed by Earl Jensen consulting as a soil scientist. Included in this survey is a soil profile description for each soil type identified on the permit area. Plate 11 depicts the soils as outlined by the Order 3 Survey performed by the SCS.

Also, please note that topsoil was removed prior to construction and stored and protected for use in final reclamation. Please see Plate 13 for a summary of stored topsoil. Appendix D also includes a topsoil mass balance and includes soil quality data from the Utah State University Testing Laboratory. The mass balance indicates that there may not be sufficient volume of topsoil for final

reclamation. Andalex has committed to identifying and testing for suitable substitute material either off the permit area or possibly within the permit area if a suitable growth medium can be identified.

Andalex has identified four different locations within the permit area to be used for revegetation test plots. These areas are all located on slopes of fill material created during the construction of the site. The object of these test areas is to determine whether or not all of the fill material within the permit area may be used as substitute topsoil for final reclamation purposes. The test plot locations are shown on Plate 1 and are located in such a fashion so as to cover the various types of fill material throughout the entire permit area. It is doubtful that the different fill areas vary with respect to chemical constituants or reclamability; however, the revegetation test plots will prove or disprove this theory. It is Andalex's goal to demonstrate that any of the fill material may be used as topsoil substitute and thereby mitigating the shortfall of topsoil gathered due to previous disturbance on site. Based on the area to be reclaimed versus the volume of topsoil currently gathered and in piles, Andalex requires that an additional 30,000 cubic yards of substitute material be identified.



The method for determining suitability of the material will be to revegetate these small test plots with Andalex's approved final reclamation seed mixture. Observations will be made over a minimum two year period to determine the extent of success.

In the unlikely event it is determined that the fill material is not suitable for topsoil substitute, Andalex will commit to locating offsite topsoil substitute material. This will have to be accomplished in conjunction with a new Bureau of Land Management right-of-way issued for this purpose; therefore, it is hoped that the fill material proves suitable.

2. Vegetation

Please refer to this chapter, Part G, re Vegetation Information. Please refer also to Appendix I which is a vegetation inventory (to be performed in the late spring or early summer of 1988). Please refer to Chapter IV, Part F, Section 5, re Revegetation Plan.

3. Topsoil Handling During Operations

3.1 Removal

Please see Chapter IV, Part F, Section 3, re Removal and Storage of Topsoil and Subsoils.

3.2 Storage

Please see Chapter IV, Part F, Section 3, re Removal and Storage of Topsoil and Subsoils.

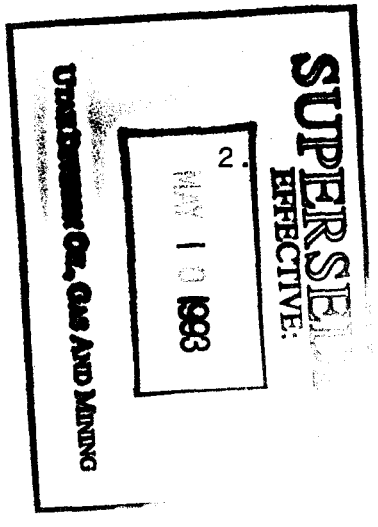
4. Reclamation of Topsoil and Substitute

Disturbed areas no longer required for the conduct of mining operations have been revegetated. Upon completion of mining activities, topsoil will be distributed and reclamation will commence as outlined in Chapter IV, Part F re Reclamation.

UMC 783.22 Land-Use Information

J. Land Use Information and Post-Mining Land Use

1. Introduction



Because of the vegetation and poor rainfall, the land is presently used only for grazing, wildlife habitat, and limited outdoor recreation. Historically, the land has also been used for coal loading.

Condition, Capability, and Productivity of the Land

Livestock grazing has been the most intense use of the permit area.

Mule deer are found within the lease area as well as the usual small mammals, predators, and passerine and raptorial birds.

State of Utah
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF OIL, GAS AND MINING

Michael O. Leavitt
Governor
Ted Stewart
Executive Director
James W. Carter
Division Director

355 West North Temple
3 Triad Center, Suite 350
Salt Lake City, Utah 84180-1203
801-538-5340
801-359-3940 (Fax)
801-538-5319 (TDD)

September 29, 1993

Mr. Mike Glasson
Andalex Resources, Inc.
P.O. Box 902
Price, Utah 84501

Re: Vegetation Test Plots, Andalex Resources, Inc., Wildcat Loadout, ACT/007/033-93A, Folder #3, Carbon County, Utah

Dear Mr. Glasson:

The recent modification to the vegetative test plots, received September 20, 1993) is hereby approved. Please notify the Division one week prior to implementation of the work as well as at the completion of work. Thank you.

Sincerely,

Pamela Grubaugh-Littig
Permit Supervisor

pgl

ANDALEX
RESOURCES, INC.
Tower Division

P.O. BOX 902
PRICE, UTAH 84501
PHONE (801) 637-5385
TELECOPIER (801) 637-8860

9/20

Septem

Susan —

For your review.

Pam

Looks good to me - in approval letter please have them notify us 1 week prior to implementation. and then at completion of work. Susan
Me too Pam
Thanks Henry

State
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355 We
Salt La

Attn:

Re: AC

Dear Ms. Jamittig:

Enclosed please find one (1) page of pertinent text from the Wildcat Loadout MRP pertaining to the vegetative test plots for which we have proposed modifications. This page describes depths and parameters for soil sampling at the new test plot west of the railroad tracks.

Regarding the additional comments:

1) The same half of Test Plot B, which had been previously sprayed with herbicide, will be sprayed again in the early spring of 1994 after the emergence of weeds.

2) A small amount of native Indian Ricegrass seed has been collected. Based on the weight of the seed collected, it will be hand-broadcast onto a proportionally sized area of the newest test plot and marked out with wooden stakes (2.5 lbs. PLS/acre).

3) The technical paper which described the "Gordon Creek" Wyoming Big Sagebrush indicates that certified seed will be available in January of 1994. Andalex will endeavor to acquire seed at that time for use in the 1994 growing season. If climate conditions permit broadcasting immediately after the seed is acquired, it will be done during the winter months. Otherwise, it will be used in the fall of 1994. Andalex will use ground markers, such as wooden stakes, to identify the location where this seed has been used on one of the test plots.

ANDALEX
RESOURCES, INC.
Tower Division

P.O. BOX 902
PRICE, UTAH 84501
PHONE (801) 637-5385
TELECOPIER (801) 637-8860

September 17, 1993

ACT/007/033 #2

Copy Sent to Ram (all)

State of Utah
Department of Natural Resources
Division of Oil, Gas & Mining
3 Triad Center, Suite 350
355 West North Temple
Salt Lake City, Utah 84180-1203

Attn: Pamela Grubaugh-Littig
Permit Supervisor

Re: ACT 007/033, Test Plots

Dear Ms. Littig:

Enclosed please find one (1) page of pertinent text from the Wildcat Loadout MRP pertaining to the vegetative test plots for which we have proposed modifications. This page describes depths and parameters for soil sampling at the new test plot west of the railroad tracks.

Regarding the additional comments:

1) The same half of Test Plot B, which had been previously sprayed with herbicide, will be sprayed again in the early spring of 1994 after the emergence of weeds.

2) A small amount of native Indian Ricegrass seed has been collected. Based on the weight of the seed collected, it will be hand-broadcast onto a proportionally sized area of the newest test plot and marked out with wooden stakes (2.5 lbs. PLS/acre).

3) The technical paper which described the "Gordon Creek" Wyoming Big Sagebrush indicates that certified seed will be available in January of 1994. Andalex will endeavor to acquire seed at that time for use in the 1994 growing season. If climate conditions permit broadcasting immediately after the seed is acquired, it will be done during the winter months. Otherwise, it will be used in the fall of 1994. Andalex will use ground markers, such as wooden stakes, to identify the location where this seed has been used on one of the test plots.

4) Additional shrub species to be added to the seed mixture are Fourwing Saltbrush, 2 lb. PLS/acre; Shadescale, 1 lb. PLS/acre; and Gardner Saltbrush, 1 lb. PLS/acre. (Revised seed list attached.)

Please call with any questions.

Sincerely,

Michael W. Glasson
Senior Geologist

mwg/rr

Michael O. Leavitt
Governor
Ted Stewart
Executive Director
James W. Carter
Division Director

State of Utah
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF OIL, GAS AND MINING

355 West North Temple
3 Triad Center, Suite 350
Salt Lake City, Utah 84180-1203
801-538-5340
801-359-3940 (Fax)
801-538-5319 (TDD)

August 4, 1993

Mr. Mike Glasson
Andalex Resources, Inc.
P.O. Box 902
Price, Utah 84501

Dear Mr. Glasson:

Re: Vegetation Test Plots, Andalex Resources, Inc., Wildcat Loadout Facility, ACT/007/033-93A, Folder #2, Emery County, Utah

Enclosed please find the analysis of the vegetation test plots submitted July 1, 1993. Please resubmit information regarding the test plots by September 10, 1993. If you have any questions, please call me.

Sincerely,

Pamela Grubaugh-Littig
Permit Supervisor

pgl
Enclosure
cc/enc: JKelley

Michael O. Leavitt
Governor
Ted Stewart
Executive Director
James W. Carter
Division Director

State of Utah
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF OIL, GAS AND MINING

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801-538-5319 (TDD)

July 30, 1993

TO: Pamela Grubaugh-Littig, Permit Supervisor

FROM: Henry Sauer, Senior Reclamation Soils Specialist

RE: Vegetation Test Plots, Andalex Resources, Inc., Wildcat Loadout Facility, ACT/007/033, Folder #2, Carbon County, Utah

Synopsis

The permittee has submitted (received July 1, 1993) a request to rework and redesign the vegetation test plots. The test plot design was the topic of discussion during an on site meeting held on May 26, 1993.

ANALYSIS

The operator has proposed a new test plot location (i.e., Test Plot D on the west side of the truck loop) as a means of determining the suitability of the fill material as a plant growth medium for final reclamation of the site. The permittee has committed to collecting soil samples. The permittee should collect samples at the same depth increments and for the same constituents as accomplished on the previous test plots. This will allow direct comparisons of test plot soils data.

RECOMMENDATION

The above analysis should be incorporated into the proposal and/or discussed with the Division.

WILDCAT.TPL

Michael O. Leavitt
Governor
Ted Stewart
Executive Director
James W. Carter
Division Director

State of Utah

DEPARTMENT OF NATURAL RESOURCES
DIVISION OF OIL, GAS AND MINING

355 West North Temple
3 Triad Center, Suite 350
Salt Lake City, Utah 84180-1203
801-538-5340
801-359-3940 (Fax)
801-538-5319 (TDD)

July 30, 1993

TO: Pamela Grubaugh-Littig, Permit Supervisor

FROM: Susan M. White, Senior Reclamation Biologist

RE: Vegetative Test Plots, Andalex Resources, Inc., Wildcat Loadout Facility, ACT/007/003, Folder #2, Carbon County, Utah

Synopsis and Analysis

Andalex submitted a design to rework the vegetation test plots for the Wildcat Loadout Facility. This design was discussed with the Division on site at a May 26, 1993 meeting. This memo will provide suggestions for changes in the proposed design.

1. The description of spraying herbicide on Test Plot B should also include the statement that the spraying will occur in early spring after emergence of weeds.

2. A description should include how the native collected Indian Ricegrass seed is to be distinguished from the "store bought" Ricegrass seed on the test plots.

3. I have enclosed a technical paper describing "Gordon Creek' Wyoming Big Sagebrush. An attempt should be made by the operator to obtain a small quantity of this seed for at least one of the test plots.

4. Atriplex shrub species are known to do well on Mancos based soils and in semiarid areas. Fourwing saltbrush, Shadescale, Gardner Saltbrush, Mat saltbrush and/or Castle Valley Saltbrush should be added to the seed mixture.

Recommendation

The above suggestions should be included in the test plot design or at minimum discussed with the Division.

United States
Department
of Agriculture

Forest Service

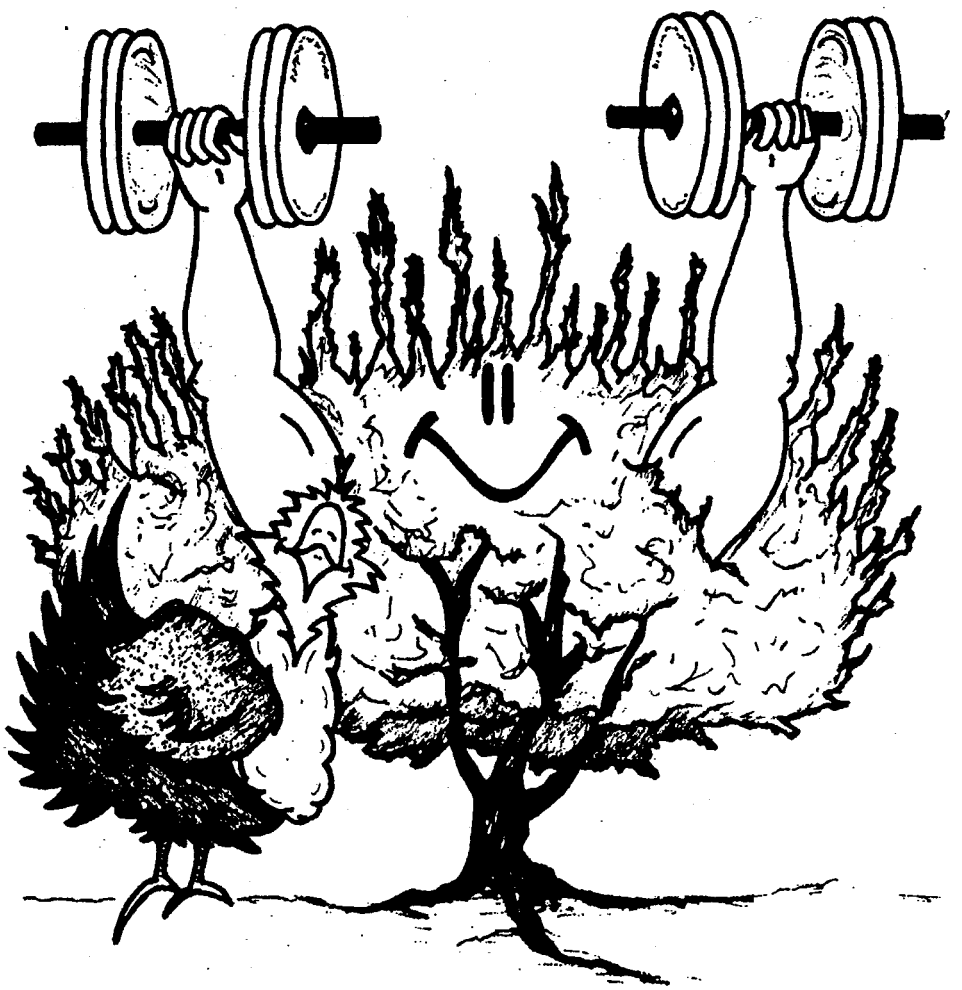
**Intermountain
Research Station**

Research Paper
INT-461

November 1992

'Gordon Creek'—A Superior, Tested Germplasm of Wyoming Big Sagebrush

Bruce L. Welch
E. Dwain Nelson
Stanford A. Young
Alan R. Sands
Fred J. Wagstaff
David L. Nelson



THE AUTHORS

BRUCE L. WELCH is a plant physiologist with the Intermountain Research Station, Provo, UT. He earned a B.S. degree in agricultural education from Utah State University in 1965, an M.S. degree in animal science from the University of Idaho in 1969, and a Ph.D. degree in plant science from the University of Idaho in 1974. He has been a Forest Service scientist since 1977.

E. DWAIN NELSON is a range conservationist for the Bureau of Land Management on the Vernal District Staff. He served as area manager in the Ely District from 1970 to 1976 and as a range conservationist in the Boise District from 1963 to 1970. He earned a B.S. degree in agronomy and chemistry in 1957 from Brigham Young University and worked as a research assistant at Utah State University studying range science and ecology from 1961 to 1963.

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RESEARCH SUMMARY

This document establishes the basis for the release of 'Gordon Creek', a superior germplasm of big sagebrush. 'Gordon Creek' is an ecotype of Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) collected near Helper, UT. This release is needed to increase nutrients in the winter diets of mule deer (*Odocoileus hemionus hemionus*) and sage grouse (*Centrocercus urophasianus*), and to restore disturbed lands. This sagebrush exceeds the typical winter forage values for energy, crude protein, phosphorus, and carotene. 'Gordon Creek' is adapted to drier sites than 'Hobble Creek', a previously released germplasm of mountain big sagebrush (*A.t.* ssp. *vaseyana*). Thirteen Wyoming big sagebrush germplasms were tested. 'Gordon Creek' was preferred by wintering mule deer and was eaten by wintering sage grouse.

'Gordon Creek' can be established and maintained over a wide geographic range on sites that have well-drained, deep or shallow soils with an average annual precipitation of 10 to 13 inches. Soil textures should not exceed 55 percent clay (sandy clay, silty clay, or clay). Soil pH may vary from 6.6 to 8.8.

'Gordon Creek' can be established by direct seeding on properly prepared seedbeds, by transplanting bareroot or containerized stock, or by a technique we term "mother plant."

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'Gordon Creek'—A Superior, Tested Germplasm of Wyoming Big Sagebrush

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THE NEED

Mule deer (*Odocoileus hemionus hemionus*) winter diets are low in energy, protein, phosphorus, and carotene (Welch and others 1986). Big sagebrush (*Artemisia tridentata*) can help raise the nutrient levels of winter diets (Bhat and others 1990; Bunderson and others 1986; Welch 1989; Welch and Wagstaff 1992).

'Hobble Creek' mountain big sagebrush (*A.t.* ssp. *vaseyana*) was formally released in 1987 for commercial production. 'Hobble Creek' was targeted for use on mule deer and domestic sheep (*Ovis aries*) winter ranges with annual precipitation of at least 14 inches (Welch and others 1986). Recent studies show that sage grouse (*Centrocercus urophasianus*) and pronghorn (*Antilocapra americana*) also prefer 'Hobble Creek' (Welch and others 1991). Managers need a preferred big sagebrush like 'Hobble Creek' for revegetation to raise the nutrient levels of winter diets on shrublands having 10 to 13 inches of annual precipitation.

METHODS

The search for superior germplasms that could be used on shrublands with 10 to 13 inches of average annual precipitation centered on Wyoming big sagebrush. It has superior winter nutrient content and is adapted to dry sites (Welch and others 1986; Winward 1983). Thirteen geographically distinct populations were selected from locations listed in table 1. Seeds collected from each population will be referred to as germplasm.

After the seeds were collected, three test sites were chosen where all 13 germplasms could be raised in common gardens. These were located near Springville, UT; Glenns Ferry, ID; and Taylor Flats in Brown's Park, UT, about 12 miles east of Dutch John. Each site was mechanically cleared of native vegetation and surrounded by a deerproof fence. During the studies, deer could be allowed to graze on the plants by opening a 15-foot-wide gate. During the spring of 1987, containerized stock of the 13 germplasms was planted on the three test sites (Nelson 1984). Each germplasm was represented by 20 plants placed at random on a 7- by 7-foot grid. During the first growing season, plants received supplementary water at Brown's Park and Glenns Ferry.

Data collected were: height of plants after the first growing season (inches), length of current year's growth for the second, third, and fourth growing seasons (inches), wintering mule deer preference (percentage of current year's growth eaten), crude protein (percentage of dry matter), phosphorus content (percentage of dry matter), in vitro digestibility (percentage of dry matter digested during laboratory tests), and number of seedlings growing within 2.5 feet of the plants (Glenns Ferry only). The techniques used to collect the data have been described

Table 1—Acquisition sites (county and state) for germplasm of Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*)

Germplasms	County	State
GORDON CREEK	Carbon	Utah
Glenns Ferry	Elmore	Idaho
Brown's Park	Daggett	Utah
Oasis	Millard	Utah
Rush Valley	Utah	Utah
South Fredonia	Coconino	Arizona
Loa	Wayne	Utah
Squaw Butte	Harney	Oregon
Dinosaur	Moffat	Colorado
North Kemmerer	Lincoln	Wyoming
Warren	Carbon	Montana
Arco	Butte	Idaho
Daniel	Sublette	Wyoming

in the following publications: McArthur and Welch 1982 (growth), Welch and Wagstaff 1992 (preference), Welch and McArthur 1979 (crude protein), Welch and others 1988 (phosphorus), and Clary and others 1988 (in vitro digestibility).

Data were analyzed by one-way analysis of variance. If an analysis of variance produced an F-value significant at the 5 percent level, we used the least significant difference method to determine which treatment means were significantly different from one another (at the 5 percent level). Each of the 13 germplasms was considered to be a treatment, with the individual plants considered to be replications. Data of equal variances were pooled. These included: height of plants for first growing season (data pooled across sites), current year's growth for the second, third, and fourth growing seasons (data pooled across years within sites), wintering mule deer preference (data pooled across sites), and nutrient content (data pooled across sites).

RESULTS

Table 2 shows the height of plants at the end of the first growing season. Plants grown from 'Gordon Creek' germplasm averaged 6.4 inches tall, significantly taller than seven of the 13 germplasms tested. 'Gordon Creek' was not significantly shorter than any of the other germplasms tested. Table 3 shows the average of the current year's growth during the second, third, and fourth growing seasons. Due to unequal variances among test sites, data could not be pooled across sites. Years within a site

Table 2—Height of 13 germplasms of Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) plants after one season of growth. Data from all three test sites were pooled. Means sharing the same letter in the superscript are not significantly different at the 5 percent level

Germplasms	Height of plants
	Inches
Oasis	6.5[a]
GORDON CREEK	6.4[a]
Rush Valley	6.4[a]
South Fredonia	6.0[ab]
Brown's Park	5.9[ab]
Loa	5.8[ab]
Squaw Butte	5.6[bc]
Dinosaur	5.4[bc]
Glenns Ferry	5.0[cd]
North Kemmerer	4.9[cde]
Warren	4.9[cde]
Arco	4.6[de]
Daniel	4.1[e]

Table 3—Leader growth of 13 germplasms of Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) grown on three different test sites. Data collected from the three test sites were not pooled. Data collected over three years within test sites were pooled. Means sharing the same letter in the superscript are not significantly different at the 5 percent level

Germplasms	Growth
	Inches
Springville Test Site	
South Fredonia	7.4[a]
GORDON CREEK	6.8[b]
Arco	6.4[bc]
Squaw Butte	6.3[bc]
Loa	6.2[bc]
Warren	6.1[bc]
Dinosaur	6.1[bc]
Oasis	5.9[cd]
Rush Valley	5.8[cd]
Glenns Ferry	5.7[cd]
Brown's Park	5.6[cd]
North Kemmerer	5.2[d]
Daniel	5.0[d]
Glenns Ferry Test Site	
GORDON CREEK	3.4[a]
Squaw Butte	3.2[a]
South Fredonia	3.1[ab]
Glenns Ferry	2.9[abc]
Oasis	2.9[abcd]
Loa	2.8[abcde]
Warren	2.8[bcde]
Brown's Park	2.8[bcde]
Dinosaur	2.6[bcde]
Arco	2.5[cde]
Daniel	2.5[cde]
North Kemmerer	2.4[de]
Rush Valley	2.3[e]
Brown's Park Test Site	
Loa	2.7
GORDON CREEK	2.6
South Fredonia	2.6
Glenns Ferry	2.5
Squaw Butte	2.5
Oasis	2.4
Rush Valley	2.4
Brown's Park	2.3
Dinosaur	2.3
Arco	2.2
Warren	2.1
North Kemmerer	2.0
Daniel	2.0

were pooled. Significant differences were detected among germplasms at the Springville and Glenns Ferry sites. 'Gordon Creek' was significantly more productive than six of the germplasms tested at Springville. Only South Fredonia germplasm was more productive there. At Glenns Ferry, the 'Gordon Creek' germplasm significantly exceeded seven other germplasms in growth. None of the other germplasms tested was significantly more productive. 'Gordon Creek' ranked second in growth at Brown's Park, but none of the differences there was significant. 'Gordon Creek' germplasm ranked among the most productive of the germplasms tested.

Preference

Table 4 shows the preference of wintering mule deer for the 13 germplasms of Wyoming big sagebrush. Because the Glenns Ferry test site had few deer, data were collected only from Springville and Brown's Park in Utah. Data collected from those sites were pooled. 'Gordon Creek' germplasm was significantly preferred by wintering mule deer (37.2 percent use) over all other germplasms. Mule deer heavily browse Wyoming big sagebrush at Gordon Creek where the germplasm was collected. Even during open winters when the deer could have moved to higher or lower elevations to feed, they still ate large quantities of the Wyoming big sagebrush there.

Table 4—Preference of wintering mule deer for 13 germplasms of Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) on the Springville and Brown's Park, UT, test sites. Data collected at the two test sites were pooled. Data are expressed as a percentage of the current year's growth removed. Means sharing the same letter in the superscript are not significantly different at the 5 percent level

Germplasms	Percent of growth used
GORDON CREEK	37.2[a]
South Fredonia	23.8[b]
Rush Valley	22.2[bc]
Warren	18.8[bcd]
Brown's Park	18.1[bcd]
Daniel	16.3[bcde]
Loa	15.8[bcde]
Glenns Ferry	14.9[bcde]
Squaw Butte	14.0[bcde]
North Kemmerer	13.4[cde]
Arco	12.3[de]
Oasis	10.9[de]
Dinosaur	7.8[e]

Table 5—Winter crude protein content among 13 germplasms of Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) grown on three test sites. Data collected from the three test sites were pooled. Data are expressed as a percentage of dry matter. Means sharing the same letter in the superscript are not significantly different at the 5 percent level

Germplasms	Percent of crude protein
Daniel	13.9[a]
North Kemmerer	13.5[ab]
Squaw Butte	13.1[ab]
Arco	13.1[ab]
Oasis	12.8[bc]
Rush Valley	12.5[bc]
GORDON CREEK	11.9[cd]
Warren	11.9[cd]
Dinosaur	11.9[cd]
Glenns Ferry	11.8[d]
Brown's Park	11.7[de]
Loa	11.3[de]
South Fredonia	10.8[e]

Nutrient Content

Table 5 shows the winter crude protein content of the 13 germplasms of Wyoming big sagebrush. Data collected from the three test sites were pooled. Four germplasms had a significantly higher crude protein content than 'Gordon Creek' (11.9 percent of dry matter). However winter crude protein levels of 'Gordon Creek' exceed the needs of wintering deer (Welch 1989) and the levels reported for many other shrubs, forbs, and grasses.

Table 6 shows the winter phosphorus content of the 13 germplasms. Data collected from the three test sites were pooled. No significant differences were detected among germplasms. 'Gordon Creek's winter phosphorus level was 0.21 percent of dry matter. This level just meets the needs of wintering deer (Welch 1989), but exceeds levels reported for some other shrubs, forbs, and grasses.

The results of the in vitro digestibility trials are shown in table 7. Data collected from the three test sites were pooled. 'Gordon Creek' digestibility (52.8 percent) was significantly exceeded by only one other germplasm (Arco, 56.6 percent). It significantly exceeded four germplasms and was not significantly different from the remaining eight. 'Gordon Creek' digestibility just meet the needs of wintering deer (Welch 1989), but exceeds the levels reported for many other shrubs and for some grasse and forbs.

Table 6—Winter phosphorus content of 13 germplasms of Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*). Data collected from all three test sites were pooled. Data are expressed as a percentage of dry matter. There was no significant difference among germplasms or sites

Germplasms	Percent of phosphorus
Oasis	0.24
North Kemmerer	.23
Squaw Butte	.23
Arco	.23
Daniel	.22
Rush Valley	.22
Warren	.22
Loa	.22
GORDON CREEK	.21
South Fredonia	.21
Brown's Park	.21
Dinosaur	.21
Glenns Ferry	.21

'Gordon Creek' is clearly a superior germplasm of Wyoming big sagebrush for revegetating winter mule deer range, sage grouse habitat, and for restoring disturbed land. The key characteristics favoring its use were wintering deer preference and its high growth rate on all three test sites.

Table 7—Winter in vitro digestibility of 13 germplasms of Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*). Data from all three test sites were pooled. Data are expressed as the percentage of dry matter digested. Means sharing the same letter in the superscript are not significantly different at the 5 percent level

Germplasms	Percent digested
Arco	56.6^{a}
Squaw Butte	55.1^{ab}
South Fredonia	53.7^{ab}
Warren	53.7^{abc}
GORDON CREEK	52.8^{bcd}
Oasis	51.7^{bcd}
Brown's Park	50.8^{cde}
Rush Valley	50.8^{cde}
Glenns Ferry	50.5^{cde}
Loa	50.4^{de}
North Kemmerer	50.1^{de}
Daniel	47.8^{e}
Dinosaur	47.7^{e}

SITE ADAPTATION

The native site of the 'Gordon Creek' germplasm is about 7 miles southwest of Helper, UT, at an elevation of about 6,000 feet. The average annual precipitation is about 12 inches. The average frost-free period is from 80 to 120 days. The soil is a Travessilla sandy loam. This is a shallow, well-drained soil derived predominantly from sandstone with a clay content of 10 to 18 percent. Effective rooting depth is between 7 and 20 inches. Soil reactions (pH) range from 7.4 to 8.8. Permeability is moderate with an available water capacity of 3 to 4 inches (Jensen and Borchert 1988; Utah State Engineer's Office 1931-60).

Glenns Ferry Site

The 'Gordon Creek' germplasm appears to be well adapted to the Glenns Ferry test site. Here 'Gordon Creek' produced 4.9 seedlings per live plant (table 8). It significantly exceeded seven other germplasms. Even the native Glenns Ferry germplasm did not have significantly more seeedlings. The growth of 'Gordon Creek' germplasm was among the highest recorded on this site (table 3). Elevation is about 3,800 feet. Average annual precipitation is about 11 inches. During the study period, however, the precipitation was 10 to 15 percent below average. The actual precipitation was probably from 9 to 10 inches. The soil is a silt loam of the Chilcott-Kunaton-Chardoton complex. This soil, derived

Table 8—Number of seedlings within 2.5 feet of 13 Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) germplasms grown at the Glenns Ferry test site. Means sharing the same letter in the superscript are not significantly different at the 5 percent level

Germplasms	Number of seedlings
Glenns Ferry	6.9^{a}
GORDON CREEK	4.9^{ab}
Brown's Park	3.4^{bc}
Squaw Butte	3.2^{bcd}
Dinosaur	2.9^{bcd}
Warren	2.6^{bcd}
Daniel	2.2^{cd}
Arco	1.6^{cd}
Rush Valley	1.5^{cd}
Loa	1.1^{cd}
Oasis	1.1^{cd}
South Fredonia	$.6^{d}$
North Kemmerer	$.5^{d}$

from loess and alluvium from various kinds of rocks is well drained. Effective rooting depth is from 20 to 30 inches. Soil reactions (pH) range from 6.6 to 8.4. Clay content ranges from 27 to 55 percent. Average frost-free period is about 110 days. Permeability is slow with available water capacity moderate (Noe 1991).

Springville Site

All 13 germplasms were adapted to the Springville test site, evidenced by high growth rates, high survival, and numerous long, branched seed stalks. All germplasms produced numerous seedlings. This site would be excellent for a seed increase garden. Elevation is about 5,000 feet. The average annual precipitation is about 16 inches. We measured 14.4 and 12.5 inches of precipitation for the 1988-89 and 1989-90 water years (author's data on file). The soil is a Pleasant Grove gravelly loam, a deep, well-drained soil derived from limestone, shale, and quartzite. Effective rooting depth is 5 feet or more. About 4 inches of available water is held by the soil to a depth of 5 feet. In summer, the soil can be dry to depths of 7 to 20 inches for more than 60 consecutive days. Soil reactions (pH) range from 7.4 to 7.9. Clay content ranges from 12 to 17 percent. The average frost-free period is about 160 days. Permeability ranges from 2.5 to 5.0 inches per hour (Swenson and others 1972).

Brown's Park Site

Due to heavy supplemental watering, it is difficult to judge the adaptation of 'Gordon Creek' germplasm to the Brown's Park site. Precipitation during the study period was just 60 to 70 percent of the 8- to 10-inch average annual precipitation. Although we believe 'Gordon Creek' would have survived the drought, supplemental watering was needed to produce enough current year's growth for the mule deer preference studies. Elevation at this site is 5,700 feet. The soil is an Abra sandy loam, a deep, well-drained soil derived from sedimentary and metamorphic rocks of the Brown's Park Formation and Mancos Shale. The effective rooting depth is 5 feet. Soil reactions (pH) range from 7.9 to 8.4. The clay content ranges from 7 to 26 percent. Average frost-free period is about 120 days. Permeability is moderate (author's data on file).

'Gordon Creek' Wyoming big sagebrush germplasm appears to be widely adapted and can be grown on sites with the following physical characteristics:

1. Mean annual precipitation of 10 to 13 inches.
2. Deep to shallow, well-drained soils.
3. Clay content up to 55 percent.
4. Soil pH between 6.6 and 8.8.
5. Growing season of at least 80 days.

ESTABLISHMENT METHODS

'Gordon Creek' big sagebrush can be established on suitable sites by direct seeding, by transplanting bareroot or containerized stock, or by a technique we term "mother plant." Descriptions of these techniques follow.

Direct Seeding

Direct seeding is the most practical method for establishing 'Gordon Creek' on areas larger than 10 acres. A successful direct-seeding program starts with high-quality, certified seed. Commercial sources of certified 'Gordon Creek' seed will be available by January 1994. Techniques have been developed to cost effectively clean the seed to a pure live seed content of 40 to 60 percent. This will greatly reduce the cost of shipping, handling, and storage. Storage life of big sagebrush seed in an open warehouse without temperature or humidity controls is about 5 years (Stevens and others 1981). If the seed analysis is over 1 year old, seedlots should be tested for germination before being used in a direct seeding program.

After a suitable site has been chosen, the next step is site preparation. This usually means total or partial removal of existing vegetation to reduce competition. Vegetation can be cleared by fire, machinery, or herbicides. The amount of vegetation removed will depend on the amount and kinds of other forage species seeded with 'Gordon Creek' big sagebrush. We recommend planting 'Gordon Creek' with other forage species because mixtures are more productive than monocultures, mixtures extend the season of use, and mixtures are more resistant to diseases and insects. 'Gordon Creek' should be sowed at the rate of one-eighth to one-fourth pound of pure live seed per acre.

The timing and depth of seeding are critical. On the native site, 'Gordon Creek' seed is dispersed by wind during early December. Therefore, we believe the best time to sow the seed is just before snow accumulation (Young and Evans 1986). For a mixture, the optimum planting depth will depend on the different species included. 'Gordon Creek' seed should be sown on a **firm** seedbed at or near the surface. In greenhouse studies, almost no seedlings emerged when big sagebrush seeds were planted deeper than three-sixteenths inch (Jacobson and Welch 1986). Frost heaving and the expansion and contraction of the soil surface by wetting and drying will cover the sagebrush seed enough so it will germinate and establish itself.

'Gordon Creek' seed can be sown by aerial seeders, cyclone seeders, dribblers, or drills that have been adjusted to leave the seeds on the surface. When using a drill, Richardson and others (1986) recommend

that sagebrush and other shrubs be planted in different rows than grasses and forbs. Because grasses and forbs develop more quickly, they may keep shrubs from becoming established. This planting technique also requires less shrub seed. Competition within the seed mixture is apparently not as much of a problem when seed is sown aerially or broadcast onto a prepared **firm** seedbed. The more diverse microhabitats available for seed placement apparently reduce competition (Young and Evans 1986).

Transplanting Bareroot and Containerized Stock

Expense limits the usefulness of transplanting bareroot or containerized stock to small, critical areas, or to seed increase gardens or demonstration plots. Planting stock should be at least 5 to 8 inches tall, overwintered in an unheated nursery bed or lathhouse. The stock can be transplanted as soon as the soil can be tilled in the spring. We recommend transplanting properly hardened stock in early spring. However, containerized stock can be successfully transplanted in the summer if it receives adequate irrigation during the first growing season.

For each transplant, an area of from 0.5 to 1 square foot must be cleared of all competing plants. This can be done by mixing the soil and killing tops, roots, stolons, and rhizomes of competing species with a shovel. Soil must be packed firmly around the transplant's entire root system. To enhance survival and growth, a 1- to 3-inch deep basin should be constructed around the stem to catch water. In extremely dry areas or during dry periods, the basin can be filled with water. For containerized stock, the growing medium should be covered with 0.5 inch of soil. This prevents the growing medium from acting as a wick and drying out the transplant. First year survival rates should be 80 percent or higher.

"Mother Plant"

This technique combines transplanting and natural seed dispersal. Shrubs established by transplanting can serve as mother plants to produce seeds for dispersal. This technique can be used after a fire or some other disturbance has destroyed a native sagebrush stand. The reduction or absence of the native stand's residual seed enhances the opportunity to establish a superior germplasm with this technique. The mother plants are planted as containerized or bareroot stock on a 50- by 50-foot grid throughout the site. Successful establishment and growth of the mother plants may require the plants to be individually fertilized, irrigated, fenced, or otherwise cared for.

After 3 to 5 years, the mother plants should produce seed. Competing vegetation can be cleared in strips or in spots around the mother plants using machinery or herbicides. This technique can help maintain big sagebrush stands that receive heavy use year after year (Wagstaff and Welch 1990). Heavy grazing may reduce seed stalk (and hence seed) production to one-thirtieth or one-fiftieth of normal (Wagstaff and Welch 1991).

CONCLUSIONS

'Gordon Creek' is a superior Wyoming big sagebrush germplasm for revegetating mule deer range, sage grouse habitat, and for restoring disturbed lands. It was preferred by wintering deer and had a high growth rate on all three test sites. It can raise the level of energy, protein, phosphorus, and carotene in the diet of a number of wintering animals.

'Gordon Creek' big sagebrush can be established by several techniques. It appears to be widely adapted and can be grown on sites with the following physical characteristics:

1. Mean annual precipitation of at least 10 inches.
2. Deep to shallow, well-drained soils.
3. Clay content up to 55 percent.
4. Soil pH between 6.6 and 8.8.
5. Growing season of at least 80 days.

REFERENCES

Bhat, R. B.; Welch, Bruce L.; Weber, D. J.; McArthur, E. Durant. 1990. Mid-winter protein, phosphorus, and digestibility of *Chrysothamnus nauseosus* subspecies. Journal of Range Management. 43: 177-179.

Bunderson, E. D.; Welch, Bruce L.; Weber, D. J. 1986. In vitro digestibility of *Juniperus osteosperma* (Torr.) Little from 17 Utah sites. Forest Science. 32: 834-840.

Clary, Warren P.; Welch, Bruce L.; Booth, Gordon D. 1988. In vitro digestion experiments: importance of variation between inocula donors. Journal of Wildlife Management. 52: 358-361.

Jacobson, Tracy L. C.; Welch, Bruce L. 1986. Planting depth of 'Hobble Creek' mountain big sagebrush seed. Great Basin Naturalist. 47: 497-499.

Jensen, Earl H.; Borchert, James W. 1988. Soil survey of Carbon Area, Utah. Price, UT: U.S. Department of Agriculture, Soil Conservation Service. 294 p.

McArthur, E. Durant; Welch, Bruce L. 1982. Growth rate differences among big sagebrush (*Artemisia tridentata*) accessions and subspecies. Journal of Range Management. 35: 396-401.

Nelson, David L. 1984. Toward producing disease-free container-grown native wildland plants. In: Murphy, P. M., compiler. The challenge of producing native plants for the Intermountain area: Proceedings: Intermountain Nurseryman's Association 1983 conference; 1983 August 8-11; Las Vegas, NV. Gen. Tech. Rep. INT-168. Ogden, UT: U.S. Department of Agriculture,Forest Service, Intermountain Forest and Range Experiment Station: 32-38.

Noe, Harley R. 1991. Soil survey of Elmore county area, Idaho: Parts of Elmore, Owyhee, and Ada counties. Boise, ID: U.S. Department of Agriculture, Soil Conservation Service. 500 p.

Richardson, B. Z.; Monsen, S. B.; Bowers, D. M. 1986. Interseeding selected shrubs and herbs on mine disturbances in southeastern Idaho. In: McArthur, E. D.; Welch, B. L., compilers. Proceedings—symposium on the biology of *Artemisia* and *Chrysothamnus*; 1984 July 9-13; Provo, UT. Gen. Tech. Rep. INT-200. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 134-139.

Stevens, R.; Jorgensen, K. R.; Davis, J. N. 1981. Viability of seed from thirty-two shrub and forb species through fifteen years of warehouse storage. Great Basin Naturalist. 41: 274-277.

Swenson, John L., Jr.; Archer, Warren M.; Donaldson, Karl M.; Shiozaki, Jungi J.; Broderick, J. Howard; Woodward, Lowell. 1972. Soil survey of Utah County, Utah-central part. Provo, UT: U.S. Department of Agriculture, Soil Conservation Service. 161 p.

Utah State Engineer's Office. 1931-1960. Normal annual precipitation map. Salt Lake City, UT.

Wagstaff, Fred J.; Welch, Bruce L. 1990. Rejuvenation of mountain big sagebrush on mule deer winter ranges using onsite plants as a seed source. In: McArthur, E. D.; Romney, E. M.; Smith, S. D.; Tueller, P. T., complilers. Proceedings—symposium on cheatgrass invasion, shrub die-off, and other aspects of shrub biology and management; 1989 April 5-7; Las Vegas, NV. Gen. Tech. Rep. INT-276. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 171-174.

Wagstaff, Fred J.; Welch, Bruce L. 1991. Seedstalk production on mountain big sagebrush enhanced through short-term protection from heavy browsing. Journal of Range Management. 44: 72-74.

Welch, Bruce L. 1989. Nutritive value of shrubs. In: McKell, Cyrus M., ed. The biology and utilization of shrubs. San Diego, CA: Academic Press: 405-424.

Welch, Bruce L.; McArthur, E. Durant. 1979. Variaton in winter levels of crude protein among *Artemisia tridentata* subspecies grown in a uniform garden. Journal of Range Management. 32: 467-469.

Welch, Bruce L.; McArthur, E. Durant; Nelson, David L.; Pederson, Jordan C.; Davis, James N. 1986. 'Hobble Creek'—a superior selection of low-elevation mountain big sagebrush. Res. Pap. INT-370. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 10 p.

Welch, Bruce L.; Pederson, Jordan C.; Rodriguez, Ronald L. 1988. Selection of big sagebrush by sage grouse. Great Basin Naturalist. 48: 274-279.

Welch, Bruce L.; Wagstaff, Fred J. 1992. 'Hobble Creek' big sagebrush vs. antelope bitterbrush as a winter forage. Journal of Range Management. 45: 140-142.

Welch, Bruce L.; Wagstaff, Fred J.; Roberson, Jay A. 1991. Preference of wintering sage grouse for big sagebrush. Journal of Range Management. 44: 462-465.

Winward, A. H. 1983. Using sagebrush ecology in wildland management. In: Johnson, K. L., ed. Proceedings, first Utah shrub ecology workshop; 1981; Ephraim, UT. Logan, UT: Utah State University: 15-19.

Young, J. A.; Evans, R. A. 1986. Seedling establishment of five sources of big sagebrush in reciprocal gardens. In: McArthur, E. D.; Welch, B. L., compilers. Proceedings—symposium on the biology of *Artemisia* and *Chrysothamnus*; 1984 July 9-13; Provo, UT. Gen. Tech. Rep. INT-200. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 370-374.

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