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A Bibliography of Bitterbrush (*Purshia tridentata* (Pursh) DC.) Annotated From 1967 to 1978

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Foreword

Bitterbrush *(Purshia tridentata* (Pursh) DC.) is one of the most widely distributed shrubs in western North America. Its value as a browse species has been recognized for more than half a century. Recent concern for the ecological significance of shrubs in natural ecosystems and the serious depletion of many big game winter ranges have led to extensive investigations of bitterbrush.

This bibliography is the result of a literature review conducted during a course of graduate study at Oregon State University. It contains information that should be of interest to both the academic and nonacademic community.

This annotated bibliography primarily contains references published after 1967, since extensive reviews were completed earlier. In 1964, Frederick C. Hall compiled an unpublished literature review of bitterbrush that circulated primarily in Region 6 of the U.S. Forest Service. Joseph V. Basile published an annotated bibliography of bitterbrush in 1967 as USDA, Forest Service Research Paper INT-44 from the Intermountain Forest and Range Experiment Station. To compile as much information as possible under one cover, the references cited by Basile and Hall are listed collectively in the Appendix. Appreciation is extended to J. V. Basile and F. C. Hall for permission to reproduce portions of their manuscripts.

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A Bibliography of Bitterbrush

ADAMS, A. W. 1972. Dendrochronology as a tool in planning wildlife habitat manipulation. *In:* Proc. Fifty-Second Annu. Conf. West. Assoc. State Game and Fish Comm. 53:321-330.

A total of 355 bitterbrush plants were partially excavated, and severed below ground level. Specimens were cross-sectioned, sanded, and examined for age structures. Twelve plants were not readable and 14 were too decayed to be reliable. Thus only 7 percent were unusable although only 23 percent of the plants were alive at time of collection. Plant ages ranged from four to 127 years.

ADAMS, A. W. 1975. A brief history of juniper and shrub populations in southern Oregon. Oregon State Wildl. Comm. Wildl. Res. Rep. 6. Oregon State Wildl. Comm., Corvallis. 33 p.

Summarizes age structure analysis in bitterbrush to reconstruct past populations of shrubs on critical winter deer range in southern Oregon. No significant differences in average density of either live or dead bitterbrush between communities was detected. Live plants averaged 58 years and dead plants 71 years. Plant establishment during the last 50 years has been poor, although if they became established, plants lived a normal life span of about 71 years. Juniper invasion is suspected as a major cause of bitterbrush reduction.

ALDERFER, J. M. 1977. A taxonomic study of bitterbrush (*Purshia tridentata* (Pursh) DC.) in Oregon. MS Thesis. Oregon State Univ., Corvallis. 197 p.

Trends for cliffrose gene flow in bitterbrush were traced through northeastern Oregon and along the eastern front of the Cascades, resulting in four distinct bitterbrush ecotypes. A low, layering ecotype growing under lodgepole pine, an ecotype similar in habit but differing in morphological characteristics on Hart Mountain, a tall, massive ecotype growing on deep soils near Janesville in northern California, and a similar columnar form growing near Durkee in northeastern Oregon, were described. Paper chromatography suggested cliffrose genes in certain populations. In all cases a diploid chromosome number of 2N=18 was found. Also, germination studies indicated that a 15 to 20 minute thiourea treatment yielded higher germination than the previously recommended five minute treatment.

ANDERSON, A. E., D. E. MEDIN, and D. C. BOWDEN. 1972. Mule deer fecal group counts related to site factors on winter ranges. J. Range Manage. 25:66-68.

Counts during 1963-1965 of mule deer fecal groups were related to 32 site factors on a Colorado winter range from 1,740 to 2,682 m elevation. Bitterbrush density and utilization accounted for the greatest variation in fecal group counts, and was the major food species.

ANDERSON, A. E., D. E. MEDIN, and D. C. BOWDEN. 1972. Mule deer numbers and shrub yield-utilization on winter range. J. Wildl. Management. 36:571-578.

Counts of mule deer fecal groups were related to mean forage yields and mean utilization of three shrubs, including bitterbrush. There was no significant correlation between indices of deer numbers and mean yield or utilization of bitterbrush. Mean yield and utilization were also not significantly correlated.

BARNEY, M. O., and N. C. FRISCHKNECHT. 1974. Vegetation changes following fire in the pinyon-juniper type of west-central Utah. J. Range Manage. 27:91-96.

Bitterbrush occurred on three of nine burn age-classes. It resprouted following fire but did not invade as quickly as little rabbitbrush or snakeweed.

BASILE, J. V. 1967. An annotated bibliography of bitterbrush (*Purshia tridentata* (Pursh) DC.). USDA Forest Serv. Res. Pap. INT-44. Intermountain Forest and Range Exp. Sta., Ogden. 27 p.

Annotates 221 references to bitterbrush through 1967.

BAYOUMI, M. A., and A. D. SMITH. 1976. Response of big game winter range vegetation to fertilization. J. Range Manage. 29:44-48.

Twig growth, seed production, and leaf and twig crude protein content of bitterbrush increased with each increment of applied nitrogen in the range of 33.6 to 168 kg/ha. Applied phosphorus had no effect on yield or utilization. In winter, elk preferred shrubs on fertilized plots.

BECKING, J. H. 1968. Nitrogen fixation of non-leguminous plants. *In:* Symposium of nitrogen in soil. Institute for Soil Fertility, Groningen, Netherlands. p. 47-74.

Bitterbrush is mentioned as a non-leguminous, nitrogen-fixing plant.

BECKING, J. H. 1970. Plant-endophyte symbiosis in non-leguminous plants. Plant and Soil 32:611-654.

Reviews literature on nitrogen fixation by non-leguminous plants in six taxonomic orders including Rosales, to which bitterbrush belongs.

BECKING, J. H. 1976. Actinomycete symbioses in nonlegumes. *In:* W. E. Newton and C. J. Nyman (Eds). Proc. First Internat. Symp. on Nitrogen Fixation. Washington State Univ. Press, Pullman. p. 581-591.

Cytology, morphology, and taxonomy of actinomycete symbionts and their host plants, including bitterbrush, are discussed.

BLACKBURN, W. H. 1975. Factors influencing infiltration and sediment production of semiarid rangelands in Nevada. Water Resources Res. 11:929-937.

Simulated rainfall was used to study infiltration and sedimentation rate on 28 sites within five watersheds in Nevada where the shrub layer included bitterbrush. Infiltration and sedimentation data are presented for each plant community and watershed.

BLAUER, A. C., A. P. PLUMMER, E. D. McARTHUR, R. STEVENS, and B. C. GIUNTA. 1975. Characteristics and hybridization of important intermountain shrubs. I. Rose Family. USDA Forest Serv. Res. Pap. INT-169. Intermountain Forest and Range Exp. Sta., Ogden. 36 p.

Describes bitterbrush and its hybridization with cliffrose and desert bitterbrush. Also summarizes literature relating to bitterbrush distribution and habitat.

BOND, G. 1976. Observations on the root nodules of *Purshia tridentata*. Proc. Royal Soc. of London 193:127-137.

In greenhouse studies, nodulated plants of bitterbrush grew satisfactorily in nitrogen-free water culture and fixed up to 40 mg of nitrogen per plant up to 16 months after planting. Acetylene assays confirmed nitrogenase activity by nodules but not by roots. Microscopic studies of nodules showed that their structure resembled that of other nonleguminous nodules.

BOYD, R. J. 1954. Effects of seed treatments upon the germination of certain browse species of Colorado. Abstract of MS Thesis submitted to Colorado A & M College. J. Range Manage. 9:170.

Germination of bitterbrush seed stratified for 70 days at –1 to 5°C was 82.5 percent compared to 1 percent for untreated seed. Acid scarification in concentrated sulfuric acid for 50 minutes resulted in 83.5 percent germination.

BURRELL, G. C. 1977. Bitterbrush (*Purshia tridentata*) in the winter ecology of the Entiat mule deer herd. MS Thesis. Univ. Washington, Seattle. 73 p.

Food habits of the Entiat mule deer herd appeared to be related to bitterbrush density. Where there was a high density of bitterbrush, deer ate primarily bitterbrush. As bitterbrush density, or the availability of preferred bitterbrush leaders decreased, mule deer ate other forage species. Fawns ate less bitterbrush than did the mature herd. Although bitterbrush is a preferred species, deer diets may shift to other highly preferred species when bitterbrush is not available. Thus, a decline in bitterbrush productivity may not be a limiting factor for the Entiat mule deer herd.

BUWAI, M. 1975. Plant vigor, herbage yield, and total nonstructural carbohydrates of several range species as influenced by defoliation treatments and rest periods. Diss. Abs. 36:1532.

Bitterbrush was most affected by late season defoliation. Defoliation appeared more detrimental to herbage yield and vigor than to total nonstructural carbohydrate levels. Herbage yield and vigor had not recovered after 14 to 26 months of rest. Heavy defoliation was more detrimental than moderate defoliation, and multiple defoliations more detrimental than single defoliations.

CALIFORNIA FOREST PEST CONTROL ACTION COUNCIL. 1970. Forest pest conditions in California, 1969. California Div. Forest., Sacramento. 21 p.

Cankers are responsible for heavy losses of bitterbrush on over 30,000 acres in northern California and southern Oregon. Early plant symptoms include the formation of swellings by twig dying and later limb or branch dying. Six possible pathogenic fungi have been cultured from the cankers.

COLWELL, R. N. 1968. Remote sensing of natural resources. Sci. Amer. 218:54-69.

Solar infrared aerial photography can be used to distinguish sagebrush from bitterbrush on rangelands. Bitterbrush appears bright red while the sagebrush is dark.

DALE, A. 1968. Comparative wood anatomy of some shrubs native to the northern Rocky Mountains. USDA Forest Serv. Res. Pap. INT-45. Intermountain Forest and Range Exp. Sta., Ogden. 73 p.

A taxonomic key based on xylem characteristics of 55 woody species is presented. Photomicrographs were used to determine vessel distribution, perforation plates, rays, and axial parenchyma. Photomicrographs and synopses of characters used in the key are presented for each species, including bitterbrush.

DALTON, D. A., and D. B. ZOBEL. 1977. Ecological aspects of nitrogen fixation by *Purshia tridentata*. Plant and Soil 48:57-80.

Acetylene reduction was used to assay nodule activity in both field and greenhouse plants. Maximum rates were observed at 20°C. Reduction rate increased linearly for five hours then declined in exised nodules, ceasing after 19 hours. Nodule activity declined in water stressed plants, essentially ceasing when xylem pressure potentials reached –25 bars. Only 46 percent of bitterbrush plants were nodulated and it was suggested that low soil temperature and poor moisture conditions were responsible. Total calculated nitrogen accretion rate was 0.057 kg N/ha/yr on a site where bitterbrush contributed 25.2 percent of vegetal cover.

DAUBENMIRE, R. 1970. Steppe vegetation of Washington. Washington Agr. Exp. Sta. Tech. Bull. 62. Washington State Univ., Pullman. 131 p.

Describes several habitat types in which bitterbrush dominates the shrub layer. Several *Purshia-Festuca* stands did not contain bitterbrush which was apparently removed by fire. It was concluded that bitterbrush is nearly always killed by a steppe fire.

DAUBENMIRE, R. 1972. Annual cycles of soil moisture and temperature as related to grass development in the steppe of eastern Washington. Ecology 53:419-424.

The annual cycle of soil moisture use and recharge was examined in several climax communities including *Purshia/Stipa*. Soil temperatures were measured at 50 and 100 cm, and data were related to phenologies of dominant grasses. Plant community distribution was found to be related more to differences in soil moisture and temperature than to chemical composition or profile characteristics of the soil.

DAUBENMIRE, R., and J. B. DAUBENMIRE. 1968. Forest vegetation of eastern Washington and northern Idaho. Washington Agr. Exp. Sta. Tech. Bull. 60. Washington State Univ., Pullman. 105 p.

Describes a *Pinus ponderosa-Purshia tridentata* habitat type. Most of this forest is an edaphic climax on sandy or stony soils. Fire eliminates only the bitterbrush but extensive movement of its achenes by rodents and birds ensures prompt reinvasion of burned areas.

DEALY, J. E. 1970. Survival and growth of bitterbrush on the Silver Lake deer winter range in central Oregon. USDA Forest Serv. Res. Note PNW-133. Pacific Northwest Forest and Range Exp. Sta., Portland. 5 p.

After two years in a four-year-old bitterbrush plantation, response was greater from browsing protection than from elimination of plant competition. Response was more evident in crown size than in plant height.

DEALY, J. E. 1971. Habitat characteristics of the Silver Lake mule deer range. USDA Forest Serv. Res. Pap. PNW-125. Pacific Northwest Forest and Range Exp. Sta., Portland. 99 p.

Bitterbrush contributes significantly to six of 21 ecosystems described.

DEALY, J. E., and J. M. GEIST. 1978. Conflicting vegetational indicators on some central Oregon scablands. J. Range Manage. 31:56-59.

On two sites where bitterbrush and low sagebrush occurred together, bitterbrush was not a reliable indicator of site conditions because landscapes that appeared to be uniform were actually highly variable with respect to internal soil characteristics.

DEITSCHMAN, G. H., K. R. JORGENSEN, and A. P. PLUMMER. 1974. Bitterbrush. *In:* Seeds of woody plants in the United States. USDA Handbook 450. p. 686-688.

Summarizes information on bitterbrush including collecting, cleaning, and storage of seeds.

DIETZ, D. R. 1968. Chemical composition and digestibility by mule deer of selected forage species, Cache la Poudre range, Colorado. Diss. Abs. 1968: 3122B.

Seasonal trends in proximate composition of several browse species including bitterbrush are presented and discussed. In feeding trials with mule deers fawns, adding pelleted lucerne to bitterbrush lowered percentage of digestability and TDN content, but improved palatability and weight gains.

DRYER, D. L., and E. K. TROUSDALE. 1978. Cucurbitacins in *Purshia tridentata*. Phytochemistry 17:325-326.

In a study designed to isolate the germination inhibitor in bitterbrush, two triterpenes, both cucurbitacins, were identified. Neither cucurbitacin was active as an inhibitor. The mother liquors from the fractions containing these triterpenes retained seed germination inhibitory activity. Normally limited to the *Cucurbitacae, Cruciferae,* and *Scrophulariaceae* families, cucurbitacins in bitterbrush account for the very bitter taste of bitterbrush seeds.

EDGERTON, P. J., B. R. McCONNELL, and J. G. SMITH. 1975. Initial response of bitterbrush to disturbance by logging and slash disposal in a lodgepole pine forest. J. Range Manage. 28:112-114.

On pumice soils in central Oregon, timber harvest practices resulted in moderately to heavily disturbed soils on 75 percent of the area and bitterbrush crown cover was reduced by 71 percent. Despite damage, bitterbrush responded quickly to more favorable growing conditions. Current twig growth doubled, and large numbers of seedlings were established on disturbed soils.

EPPS, G. A. VAN. 1974. Shrub seed production—a potential enterprise. Utah Sci. 35:21-23.

Production of seed from several shrub species, including bitterbrush, is discussed. Various aspects of growing shrubs for seed are emphasized.

EVANS, R. A., and J. A. YOUNG. 1977. Bitterbrush germination with constant and alternating temperatures. J. Range Manage. 30:30-32.

Germination of bitterbrush seeds was greatest with cold night temperatures in the optimum range of 2 to 5°C for stratification. Warm daytime temperatures of 10 to 40°C gave relatively high germination when nighttime temperaures were in the stratfication range. Thiourea treatment expanded the number of temperature regimes that gave maximum germination, and also increased amount of germination at all temperature ranges.

EVERETT, R. L., and R. O. MEEUWIG. 1975. Hydrogen peroxide and thiourea treatment of bitterbrush seed. USDA Forest Serv. Res. Note INT-196. Intermountain Forest and Range Exp. Sta., Ogden. 6 p.

Seeds of bitterbrush were exposed to 12 different germination-stimulating treatments. In subsequent germination trials overall emergence was 10 percent greater than in untreated controls. Soaking in 1 percent H_2O_2 and shaking for three, five, or seven hours during exposure gave the best results. It was suggested that H_2O_2 treatments may reduce frost damage to seedlings since only a few seedlings emerged at one time.

EVERETT, R. L., R. O. MEEUWIG, and J. H. ROBERTSON. 1978. Propagation of Nevada shrubs by stem cuttings. J. Range Manage. 21:426-429.

Stem cuttings of 54 Nevada shrub species were tested for rooting capacity. Four percent of 110 total bitterbrush cuttings sprouted.

EVERETT, R. L., R. O. MEEUWIG, and R. STEVENS. 1978. Deer mouse preferences for seed of commonly planted species, indigenous weed seed, and sacrifice foods. J. Range Manage. 31:70-73.

Captive deer mice from three western plant communities were fed seed from 18 grass, forb, and shrub species. Mice consumed seed equal to one-third of their body weight daily. Bitterbrush was the most preferred seed accounting for 10.2 to 30.7 percent of mice diets in five trials. The lowest value was obtained in the last trial where bitterbrush seed was coated with alpha-naphthy-thiourea, a rodent pesticide repellent.

FARNSWORTH, R. B. 1976. Nitrogen fixation in shrubs. *In:* H. C. Stutz (Ed). Wildland shrubs: symposium and workshop. Brigham Young Univ., Provo. p. 32-71.

Discusses evidence for and the role of nitrogen fixation in several shrubs, including bitterbrush.

FERGUSON, C. W. 1959. Growth rings in woody shrubs as potential aids in archaeological interpretation. The Kiva 25:24-30.

Bitterbrush stems contain a highly sensitive ring pattern that can readily be dated despite irregular stem forms. Small or nearly absent rings, or false layers in larger rings do not detract from datability of ring sequences. Sensitivity of bitterbrush growth layers makes it an ideal species for ecological studies.

FERGUSON, R. B. 1968. Survival and growth of young bitterbrush browsed by deer. J. Wildl. Manage. 32:769-772.

On two sites near the Payette River in southwest Idaho, browsed bitterbrush plants were compared to protected plants. On one site there was no difference, but on the other site survival of protected shrubs was 20 percent greater than unprotected plants. Mean surface area of protected plants was 1.6 to 3.4-fold greater than that of browsed plants, and young shrubs moderately browsed each winter remained smaller than unbrowsed shrubs.

FERGUSON, R. B. 1972. Bitterbrush seedling establishment as influenced by soil moisture and soil surface temperature. J. Range Manage. 25:47-49.

Bitterbrush seeds exposed to field conditions for 80 days following seed dispersal exhibited reduced viability. Exposure of seeds to dry heat for periods up to 15 hours did not reduce germination percentage until temperature exceeded 80°C. Seedling survival and growth were significantly affected by both artificial watering and slope exposure.

FERGUSON, R. B. 1972. Bitterbrush topping: shrub response and cost factors. USDA Forest Serv. Res. Pap. INT-125. Intermountain Forest and Range Exp. Sta., Ogden. 11 p.

Following mechanical removal of 30 to 50 percent of bitterbrush crowns, annual twig growth increased considerably, then gradually decreased over a four-year period. After four years twig growth remained greater than on untopped shrubs, however. No detrimental effects on shrub longevity or increased insect attack or disease damage resulted from topping. Using chain saws, costs of $9.00 to $21.00 per acre can be expected on stands of similar density.

FERGUSON, R. B., and M. A. MARSDEN. 1977. Estimating over-winter bitterbrush utilization from twig diameter-length-weight relations. J. Range Manage. 30:231-236.

Methods are described for estimating mean utilization of individual twigs by both length and weight. Caution should be used when extrapolating techniques outside southern Idaho.

FERGUSON, R. B., and S. M. MONSEN. 1974. Research with containerized shrubs and forbs in southern Idaho. *In:* R. W. Tinus, W. I. Stein, and W. E. Balmer (Eds). Proc. North Amer. Containerized Forest Tree Seedling Symp. Great Plains Agr. Council Pub. 68. p. 349-358.

A potting mixture of shredded peat moss, horticultural vermiculite, and several supplemental nutrients was used to grow bitterbrush seedlings. When supplemented with a slow-release fertilizer (18-6-12), potted seedlings had greater emergence, larger plants at one month, and larger and taller plants at two months. Thus, the benefits of fertilizing seemed to be primarily in larger, more robust seedlings at planting time. Also, reasonable success was achieved in suppressing damping-off by using a mixture of Benlate and Dexon applied as a drench immediately after sowing seed and again at the beginning of germination.

FRANKLIN, J. F., AND C. T. DYRNESS. 1973. Natural vegetation of Oregon and Washington. USDA Forest Serv. Gen. Tech. Rep. PNW-8. Pacific Northwest Forest and Range Exp. Sta., Portland. 417 p.

Describes 18 habitat types or associations in Oregon of which bitterbrush is a major component.

FRANKLIN, J. F., and C. T. DYRNESS. 1969. Vegetation of Oregon and Washington. USDA. Forest Serv. Res. Pap. PNW-80. Pacific Northwest Forest and Range Exp. Sta., Portland. 216 p.

See Franklin and Dyrness, 1973.

FURNISS, M. M. 1972. A preliminary list of insects and mites that infest some important browse plants of western big game. USDA. Forest Serv. Res. Note INT-155. Intermountain Forest and Range Exp. Sta., Ogden. 16 p.

Lists 82 species of insects and mites known or suspected of utilizing or damaging bitterbrush.

FURNISS, M. M., and R. G. KREBILL, 1972. Insects and diseases of shrubs on western big game ranges. *In:* C. M. McKell, J. P. Blaisdell, and J. R. Goodin (Eds). Wildland shrubs—their biology and utilization. USDA Forest Serv. Gen. Tech. Rep. INT-1. Intermountain Forest and Range Exp. Sta., Ogden. p. 218-226.

Summarizes literature on insect and disease enemies of four western shrubs, including bitterbrush.

GIUNTA, B. C., D. R. CHRISTENSEN, and S. B. MONSEN. 1975. Interseeding shrubs in cheatgrass with a browse seeder-scalper. J. Range Manage. 28:398-402.

In seeding trials over a five-year period at 1737 m elevation, four browse species were sown in different scalp widths in dense cheatgrass. Scalp width had a highly positive effect on shrub survival after five years, with the greatest response shown by bitterbrush. Herbage production per plant was not affected by scalp width but total production per plot increased as a result of an increase in number of plants per plot.

HALL, F. C. 1964. Literature review of bitterbrush *(Purshia tridentata)*. Unpublished manuscript. USDA Forest Service. Pacific Northwest Region (6), Portland. 48 p.

Provides an extensive review of bitterbrush literature including 109 references.

HANSEN, R. M., R. C. CLARK, and W. LAWHORN. 1977. Foods of wild horses, deer, and cattle in the Douglas Mountain area, Colorado. J. Range Manage. 30:116-119.

In an area of modernate occurrence, bitterbrush contributed less than one percent to the diets of wild horses and cattle, and one percent for deer. Diets were determined from microscopic analysis of fecal material collected during the summer of 1975 but without regard to season of production.

HANSEN, R. M., and B. L. DEARDEN. 1975. Winter foods of mule deer in Piceance Basin, Colorado. J. Range Manage. 28:298-300.

Bitterbrush, big sagebrush, and Utah serviceberry contributed 14 percent to deer diets on a pinyon-juniper-sagebrush site in early December and nine percent in March. On a pinyon-juniper site, these three species contributed 41 and 12 percent during the same periods. Shrub contribution generally decreased and tree utilization generally increased through the winter period.

HARNISS, R. O., and R. B. MURRAY. 1973. 30 years of vegetal change following burning of sagebrush-grass range. J. Range Manage. 26:322-325.

During August 1936, 460 acres of sagebrush-grass range on the Upper Snake River Plains near Dubois, Idaho, were burned. In 1936, bitterbrush occurred only on the heavily burned plots. By 1948, small amounts had appeared on unburned plots. In 1966, bitterbrush had also appeared on lightly burned and moderately burned plots. The increase of bitterbrush might be related to the area's history of use or to weather factors that allowed invasion of a dense sagebrush stand.

HARPER, L. W. 1970. The use of thiourea for laboratory germination of antelope bitterbrush seed. Proc. Assoc. Official Seed Analysts 60:127-131.

Seeds of bitterbrush were soaked from 2 to 512 minutes in 1, 2, or 4 percent thiourea solutions and germinated under three temperature conditions. Soaking for 128 minutes in 2 percent solution gave the best results. However, toxic symptoms increased with thiourea concentration and soaking time. Germination of seed soaked in tap water for 48 hours on blotters moistened with 0.2 percent thiourea, 0.2 percent KNO_3, or both, was 78.7, 9.0, and 19.5 percent, respectively.

HEIT, C. E. 1970. Germinative characteristics and optimum testing methods for twelve western shrub species. Proc. Assoc. Official Seed Analysts 60:197-205.

Information is presented on optimum germination procedures and testing methods for various shrub species including bitterbrush.

HICKMAN, O. E. 1975. Seasonal trends in the nutritive content of important range forage species near Silver Lake, Oregon. USDA Forest Serv. Res. Pap. PNW-187. Pacific Northwest Forest and Range Exp. Sta., Portland. 32 p.

Seasonal trends in moisture content, crude protein, crude fiber, crude fat, ash, calcium, phosphorus, apparent digestibility, and calcium:phosphorus ratio are reported for bitterbrush along with seven grass or grasslike plants, four forbs, and five other shrubs.

HUBBARD, R. L. 1956. The effects of plant competition on the growth and survival of bitterbrush seedlings. USDA Forest Service. California Forest and Range Exp. Sta. Res. Note 109, Berkeley. 9 p.

Bitterbrush seedling mortality was about equal until July 13 under negligible, light, and heavy levels of competition. Mortality at that date was attributed primarily to cutworms and other insects. At the end of the first growing season, heavy competition from native vegetation and crested wheatgrass re-

sulted in higher mortality than either light or negligible competition. At the end of the third growing season, over half of the seedlings in the heavy competition plots were dead, compared to about 21 percent in light and negligible competition plots. (see also HUBBARD, R. L. 1957. The effects of plant competition on the growth and survival of bitterbrush seedlings. J. Range Manage. 10:135-137.)

HUDSON, R. J., D. M. HERBERT, and V. C. BRINK. 1976. Occupational patterns of wildlife on a major East Kootenay winter-spring range. J. Range Manage. 29:38-43.

Whitetail deer preferred lower ground with a high shrub density, while mule deer preferred more open shrub communities, especially bitterbrush, in rugged country at higher elevations. Cattle grazing had little effect on the distribution of wildlife. Partial correlation analysis applied to 14 environmental parameters appeared useful for quantifying habitat use behavior and for resolving some ambiguities of overlapping habitat preferences.

HULL, A. C., JR. 1974. Species for seeding arid rangeland in southern Idaho. J. Range Manage. 27:216-218.

Forty-eight of 90 tested species failed completely. Bitterbrush had an average rating of very poor or less.

HULL, A. C. JR., and M. K. HULL. 1974. Presettlement vegetation of Cache Valley, Utah and Idaho. J. Range Manage. 27:27-29.

Explorers and early settlers in Cache Valley found abundant grass and little sagebrush. Bitterbrush was the second most abundant shrub.

ISKANDER, F. D. 1974. Factors affecting feeding habits of sheep grazing foothill ranges of northern Utah. Diss. Abs. 35:1146.

Sheep grazing was heaviest around shrubs, and sheep oriented themselves toward conspicuous objects while grazing. Presence of big sagebrush decreased utilization of neighboring bitterbrush.

JENSEN, C. H., and G. W. SCOTTER. 1977. A comparison of twig-length and browsed twig methods of determining browse utilization. J. Range Manage. 30:64-67.

Bitterbrush and cliffrose were used to compare two methods of determining browse utilization. Estimating the percentage of browsed twigs or calculating percentages from counts of browsed and unbrowsed twigs provided higher utilization than measuring twig lengths. Estimating percentages of browsed twigs resulted in high individual bias in heavy-use areas while calculating percentages of utilization from twig length measurements provided equal sensitivity throughout the 0 to 100 percent range. Twig measurement data were more consistent among observers than estimates. Measuring twig lengths required about four times more man-hours than estimating percentages or counting twig numbers.

JENSEN, C. H., A. D. SMITH, and G. W. SCOTTER. 1972. Guidelines for grazing sheep on rangelands used by big game in winter. J. Range Manage. 25:346-352.

Sheep grazed at two intensities on 12 areas of big game winter range at 1,737 to 1,890 m elevation, during six different periods, selected bitterbrush after mid-July. Bitterbrush availability to game was reduced in proportion to percentage used by sheep. Bitterbrush was the most abundant and desirable forage and was not impaired by any of the grazing systems used.

JENSEN, H. 1942. A study of seasonal variation of the composition of forage plants of southeastern Oregon. MS Thesis. Oregon State Univ., Corvallis. 40 p.

Discusses nutritional data for five grass species and bitterbrush. Crude protein levels in bitterbrush ranged from a high of 14.09 percent in June to a low of 7.51 percent in December 1938. Crude protein for 1941 varied less, from a high of 11.17 percent in May to a low of 8.65 percent in October.

JENSEN, N. E. 1972. Pinyon-juniper woodland management for multiple use benefits. J. Range Manage. 25:231-234.

Silvicultural and regeneration practices including stump culture, pruning, thinning, weeding, and tube stock planting were initiated to improve Christmas tree, juniper fence post, and forage production, wildlife habitat, and soil and watershed values. Overstory removal effectively released bitterbrush, increasing the number of twigs by 42 percent and leader growth by 100 percent over the control area. Bitterbrush cover increased by 28 percent.

JOHNSON, A. H., and G. A. SMATHERS. 1976. Fire history and ecology, Lava Beds National Monument. *In:* Tall Timbers Fire Ecol. Conf. 15. Tall Timbers Res. Sta., Tallahassee. p. 103-115.

Today this forest is filled with an understory of mountain mahogany and antelope bitterbrush. Although these two shrubs were components of the original community, frequent fires held them in check. Excessive density of these shrubs not only reduces pine reproduction but also greatly increases the fuel loadings and therefore the possibility of a conflagration which might destroy the entire community.

KLEMMEDSON, J. O., and R. B. FERGUSON. 1969. Response of bitterbrush seedlings to nitrogen and moisture on a granitic soil. Soil Sci. Soc. Amer. Proc. 33:962-966.

Bitterbrush seedlings were grown in pots of granitic soil taken from a bitterbrush site in southern Idaho. Soils from depths of 0-15, 15-40, and 40-90 cm were used with nitrogen supplements of 0, 34, and 100 kg/ha and two moisture regimes. Nitrogen caused seedling yields to decrease on the upper two layers, but to increase on soil from the 40 to 90 cm layer.

The high moisture regime reduced adverse effects of added nitrogen on seedlings grown in the surface layer, but increased the adverse effect on seedlings grown in lower soil layers. Subsequently, bitterbrush responded negatively or gave no response to added nitrogen in soils proven to deficient in nitrogen for barley. Yields of bitterbrush decreased when nitrogen in plants reached about two percent.

KLEMMEDSON, J. O., and R. B. FERGUSON. 1973. Effect of sulfur deficiency on yield and nitrogen content in bitterbrush (*Purshia tridentata*) seedlings on granitic soils. Soil Sci. Soc. Amer. Proc. 37:947-951.

Bitterbrush seedlings were supplemented NPK, NPS, or NPKS, in soils which showed slight to marked sulfur deficiency. Weight of bitterbrush seedlings was significantly lower on NPK treatments than on NPS or NPKS treatments, but total nitrogen was 2.07 percent compared with 1.15 percent when sulfur was included. Subsequent additions of sulfur suggested that bitterbrush can grow satisfactorily on soils that are very low in nitrogen and sulfur, but less satisfactorily on soils where sulfur is much less available than nitrogen. It was recommended that where bitterbrush is grown on granitic soils and where fertilization is contemplated, that available nitrogen and sulfur be properly balanced.

KREBILL, R. G. 1972. Preliminary annotated list of diseases of shrubs on western game ranges. USDA Forest Serv. Res. Note INT-156. Intermountain Forest and Range Exp. Sta., Ogden. 8 p.

Lists root rot, root-stem cankers, a parasitic plant, damping-off, dieback, drought, and frost as injurious to bitterbrush.

KREBILL, R. G., and J. M. MUIR. 1974. Morphological characterizaztion of *Frankia purshiae,* the endophyte in root nodules of bitterbrush. Northwest Sci. 48:266-268.

Histological analyses were made of root nodules of bitterbrush collected in Idaho and Utah. Hypertrophied parenchyma cells in the cortex of nodules contained an endophyte characterized by obovoid vesicles connected to ends of narrow hyphae. The taxon *Frankia purshiae* (Becking) is recommended for this endophyte.

KUFELD, R. C. 1973. Foods eaten by the Rocky Mountain elk. J. Range Manage. 26:106-113.

Forty-eight food habit studies were surveyed to summarize data on plants normally eaten by Rocky Mountain elk. Bitterbrush was rated as a highly valuable plant in winter and fall.

KUFELD, R. C., O. C. WALLMO, and C. FEDDEMA. 1973. Foods of the Rocky Mountain mule deer. USDA Forest Serv. Res. Pap. RM-111. Rocky Mountain Forest and Range Exp. Sta., Fort Collins. 31 p.

Ninety-nine food habit studies were surveyed to summarize data on plants normally eaten by mule deer. Bitterbrush use was rated heavy during winter, summer, and fall, and moderate during spring.

LANGHAM, J. M. 1971. Nitrogen in relation to plant succession on intradune cobble flats, with emphasis on germination and growth. Diss. Abs. 32:2655.

Four seral communities were described on advancing dunes near the Hanford Atomic Reservation in Washington, including a *Purshia tridentata/ Chrysothamnus nauseosus* stage and a *P. tridentata/Poa sandbergii* stage. Seeds of four late-seral pioneer species, including bitterbrush, were germinated in pots containing control, low, and high nitrogen levels. Bitterbrush germinated best in low-nitrogen pots with N levels similar to dunes in late seral stages.

LAVIN, F., and T. N. JOHNSON, Jr. 1977. Species adapted for planting Arizona pinyon-juniper woodland. J. Range Manage. 30:410-415.

Bitterbrush was rated fair/good for planting on only one of ten sites in central Arizona. The successful site was at 1981 m with 43 cm annual precipitation and a mean annual temperature of 9°C on Jacques loam soil.

LAYCOCK, W. A. 1961. Improve your range by heavy fall grazing. Nat. Woolgrower 51(6):16, 30.

Mentions that sheep seldom eat shrubs in the spring, except the flowers of bitterbrush.

LAYCOCK, W. A. 1967. How heavy grazing and protection affect sagebrush-grass range. J. Range Manage. 20:206-213.

Bitterbrush production decreased on good and poor condition range under fall or spring grazing, and also within exclosures. The large decrease in production was probably caused by damage from tent caterpillars in 1958-1960. In 1960 almost all bitterbrush plants were completely defoliated. By 1964 many were partly or completely dead.

LAYCOCK, W. A. 1969. Exclosures and natural areas on rangelands in Utah. USDA Forest Serv. Res. Pap. INT-62. Intermountain Forest and Range Exp. Sta., Ogden. 44 p.

Bitterbrush is a major component in ten of 529 exclosures and natural areas in Utah.

LESPERANCE, A. L., P. T. TUELLER, and V. R. BOHMAN. 1970. Symposium on pasture methods for maximum production in beef cattle: competitive use of the range forage resource. J. Anim. Sci. 30:115-121.

Cattle rumen samples indicated that they selected 80 percent grass when available, but shifted to some browse, primarily bitterbrush, in the fall. Deer selected browse on summer and winter ranges to about the same extent that cattle selected grass, although deer tended to select three to five browse species while cattle concentrated on one site-specific species. Some late autumn competition existed between deer and cattle for bitterbrush.

LYON, L. J. 1968. An evaluation of density sampling methods in a shrub community. J. Range Manage. 21:16-20.

Nineteen variations of quadrat and plotless sampling techniques were used to estimate density of bitterbrush in a population with known parameters. All methods needed unreasonably large samples to give acceptable precision, many methods would not produce a correct answer with any size sample, and several methods required more effort than counting all plants. Visual estimation techniques or non-random sampling methods may be the most realistic approach to density sampling.

McARTHUR, E. D., B. C. GIUNTA, and A. P. PLUMMER. 1974. Shrubs for restoration of depleted ranges and disturbed areas. Utah Sci. 32:28-33.

Shrub species valuable for browse production, including bitterbrush, are described. A table of 34 species is presented showing value for restoration of rangeland and soil stabilization, and the vegetation types to which they are best suited.

McCONNELL, B. R., and J. G. SMITH. 1970. Response of understory vegetation to ponderosa pine thinning in eastern Washington. J. Range Manage. 23:208-212.

Shrubs, mostly bitterbrush, increased production about 2.2 kg/ha for each 30.5 cm increase in pine spacing, and about 1.1 kg/ha for each 1 percent decrease in pine canopy.

McCONNELL, B. R., and J. G. SMITH. 1970. Some effects of grazing intensity on bitterbrush dispersion. J. Range Manage. 23:92-94.

Fenceline comparisons in a uniform habitat showed bitterbrush density was reduced by heavy grazing but not affected by moderate use. Large increases in mean area per plant under heavy grazing did not alter overall form of random population dispersion. Inclusion of one-year-old plants on moderately used areas caused aggregation of the population but not on the heavily used areas. Contrasting reaction probably resulted from a differential pattern of seedling mortality due to different amounts of herbaceous understory in the two shrub populations.

McCONNELL, B. R., and J. G. SMITH. 1971. Influence of grazing and age on crown characteristics in bitterbrush. USDA Forest Serv. Res. Note PNW-146. Pacific Northwest Forest and Range Exp. Sta., Portland. 4 p.

Changes in average crown diameter and percentage of dead crown were related to bitterbrush age on moderately and heavily grazed ranges. There was a significant difference in average crown diameter under different grazing levels but differences between percentages of dead crown area were not significant.

McCONNELL, B. R., and J. G. SMITH. 1977. Influence of grazing on age-yield interactions in bitterbrush. J. Range Manage. 30:91-93.

Significant relationships were found between yield and age of bitterbrush. Plants that were heavily grazed during the spring and early summer produced more forage than plants that were moderately grazed during late summer and fall. Under heavy grazing, plant longevity was reduced and fewer plants survived until the age of maximum production. Consequently only 88 kg/ha of air-dry forage were produced under heavy early grazing compared with 172 kg/ha under moderate late-season grazing.

MARTIN, R. E. 1978. Fire manipulation and effects in western juniper. *In:* R. E. Martin, J. E. Dealy, and D. L. Caraher (Eds). Proc. Western Juniper Ecol. and Manage. Workshop. USDA Forest Serv. Gen. Tech. Rep. PNW-74. Pacific Northwest Forest and Range Exp. Sta., Portland. p. 121-136.

Discusses plant succession in juniper ecosystems with and without periodic fire. Also reports that on burns with high soil moisture, up to 30 percent of bitterbrush sprouted, but never more than 10 percent were left the second year.

MEDIN, D. E., and R. B. FERGUSON. 1972. Shrub establishment on game ranges in the northwestern United States. *In:* C. M. McKell, J. P. Blaisdell, and J. R. Goodin (Eds). Wildland shrubs—their biology and utilization. USDA Forest Serv. Gen. Tech. Rep. INT-1. Intermountain Forest and Range Exp. Sta., Ogden. p. 359-368.

Principles and procedures of seeding game ranges are discussed. In an example of seeding success, a ten-year-old bitterbrush seeding near Boise produced over 620 pounds of oven-dry twig material per acre in a stand with about 700 plants per acre.

MENKE, J. W. 1974. Effects of defoliation on carbohydrate reserves, vigor, and herbage yield for several important Colorado range species. Diss. Abs. 35:632.

Amounts and distributions of rainfall on an intermountain shrubland type in northern Colorado that caused increased seasonal growth resulted in lower seasonal total available carbohydrate storage. Bitterbrush was detrimentally affected by defoliation during late spring and summer at fruit development or seed shatter stages. Multiple defoliations were more detrimental than most single defoliations at any phenological stage. Plant vigor and herbage yield were more easily depressed than carbohydrate reserve storage.

(see also: MENKE, J. W. 1974. Effects of defoliation on carbohydrate reserves, vigor, and herbage yield for several important Colorado range species. PhD Diss. Colorado State Univ., Fort Collins. 311 p.)

MONSON, S. B., and D. R. CHRISTENSEN. 1976. Woody plants for rehabilitating rangelands in the intermountain region. *In:* H. C. Stutz (Ed). Wildland shrubs: symposium and workshop. Utah State Univ., Logan. p. 72-119.

Discusses shrub management in the intermountain region. Describes plant selection criteria, recent developments in plant selection, use of bare-root and containerized planting stock, and wildland disturbances. Bitterbrush is discussed throughout.

NEAL, D. L., and H. R. SANDERSON. 1975. Thiourea solution temperature and bitterbrush germination and seedling growth. J. Range Manage. 28:421-423.

Seed collections were treated in thiourea solutions at 18 temperatures ranging from –1 to 93°C. Normal germination and seedling growth occurred following treatments between 16 and 60°C. Below 16°C germination rate declined slightly but seedling growth was normal. Seedling deformities began to appear above 60°C, and germination declined rapidly. Deformities consisted of annual cracks around the hypocotyls and detached root caps.

NORD, E. C., and C. M. COUNTRYMAN. 1972. Fire relations. *In:* C. M. McKell, J. P. Blaisdell, and J. R. Goodin (Eds). Wildland shrubs—their biology and utilization. USDA Forest Serv. Gen. Tech. Rep. INT-1. Intermountain Forest and Range Exp. Sta., Ogden. p. 88-97.

Discusses fuel loading, arrangement, moisture content, heat content, and chemical composition of several shrubs. Moisture content of living fuel was related to ash content. Bitterbrush foliage and current leaders had 147 percent moisture content in May, smaller foliage and stems had 131 percent, and ash content was 3.8 percent on a dry matter basis.

PEEK, J. M., F. D. JOHNSON, and N. N. PENCE. 1978. Successional trends in a ponderosa pine-bitterbrush community related to grazing by livestock, wildlife, and to fire. J. Range Manage. 31:49-53.

A ponderosa pine/bitterbrush community near the Salmon River, Idaho, was determined to be a seral stage of a Douglas fir/snowberry habitat type. Bitterbrush density was similar outside and inside a big game exclosure, but twig production was 12 times greater outside. Utilization by big game of this vegetation has maintained the productivity of bitterbrush and retarded succession to climax.

PERRY, D. A., and J. E. LOTAN. 1977. Regeneration and early growth on strip clearcuts in lodgepole pine/bitterbrush habitat type. USDA Forest Serv. Res. Note INT-238. Intermountain Forest and Range Exp. Sta., Ogden. 7 p.

A lodgepole pine/bitterbrush habitat type near West Yellowstone, Montana is described as exceptionally droughty and nutrient poor.

PFISTER, R. D., and R. DAUBENMIRE. 1975. Ecology of lodgepole pine (*Pinus contorta* Dougl.). *In:* D. M. Baumgartner (Ed). Management of lodgepole pine ecosystems Symp. Proc. Washington State Univ. Coop. Ext. Serv., Pullman. p. 27-56.

Bitterbrush is the shrub layer dominant in four of 11 recognized climax lodgepole pine communities. Environmental conditions include well-drained pumice soils, seasonally wet pumice soils, obsidian sands, frost pockets, and subalpine climates.

PHILLIPS, T. A. 1970. The status of antelope bitterbrush in the Cassia Mountain area of southern Idaho. Range Improvement Notes 15 (4):1-15. USDA Forest Service. Intermountain Region, Ogden.

Bitterbrush age-form classes indicated that less than 1 percent were seedlings, 5 percent were young, 65 percent mature, and 30 percent decadent. Ring counts on four distinct sites indicated that plants on canyon rims averaged ten years older than plants on toe slopes, canyon slopes, and ridgetops. This was attributed to greater natural fire protection on canyon rims. On the four sites, plant ages ranged from 4 to 130 years with an average of 45 years. About 18 percent of all plants layered. It was suggested that three consecutive years of above normal moisture may be required for effective leader growth, seed production, and establishment. Historically, bitterbrush was able to reproduce and become established under extremely heavy grazing pressure. Fire has killed more bitterbrush than all other agents combined. Little or no reestablishment has occurred on most burns, although date of burning may be important in recovery.

PLUMMER, A. P., D. R. CHRISTENSEN, and S. B. MONSEN. 1968. Restoring big-game range in Utah. Utah Div. Fish and Game Pub. 68-3, Ephraim, 183 p.

Discusses principles and procedures of successful range restoration with guides for seeding specific vegetal types. Describes precipitation zones and soils to which bitterbrush is adapted. Recommends that low, layering forms be used for stabilizing and beautifying roadcuts and exposed sites. Low, layering forms also recover much better after burning; in some areas recovery has been virtually 100 percent but this is unusual.

PLUMMER, A. P., D. R. CHRISTENSEN, R. STEVENS, and N. V. HANCOCK. 1970. Improvement of forage and habitat for game. *In:* Proc. Fiftieth Annu. Conf. West. Assoc. State Game and Fish Comm. 50:430-441.

Hand planting of bitterbrush has been replaced by seed dribblers mounted on crawler tractors which drop seed in cleat marks. Bitterbrush is an important artifically established species on restored game ranges. Ten principles for successful seeding are listed.

PLUMMER, A. P., D. R. CHRISTENSEN, R. STEVENS, and K. R. JORGENSEN. 1970. Highlights, results, and accomplishments of game range restoration studies. Utah State Div. Fish and Game Pub. 70-3, Logan. 94 p.

Summarizes results of studies on species selection, site determination, germination techniques, site preparation and planting, and protection of plantings. Bitterbrush is mentioned throughout.

REGELIN, W. L., R. M. BARTMAN, D. W. REICHERT, and P. H. NEIL. 1976. The influence of supplemental feed on food habits of deer. USDA Forest Serv. Res. Note RM-316. Rocky Mountain Forest and Range Exp. Sta., Fort Collins. 4 p.

Tame mule deer exposed to unlimited amounts of concentrated feed selected the same forage species, in similar proportions, as did deer that received no supplemental feed. Of the nine species which comprised 93 percent of all bites taken, bitterbrush contributed 39.1 percent.

RICHENS, V. B. 1967. Characteristics of mule deer herds and their range in northeastern Utah. J. Wildl. Manage. 31:651-666.

On the Daggett winter range, bitterbrush was an important supplemental mule deer food. It accounted for 6.9 percent of rumen weight although it comprised only 0.6 percent of the total ground cover. By age classes, 92.2 percent of bitterbrush plants were mature, 6.1 percent young, 1.3 percent decadent, and 0.4 percent seedlings.

RICKARD, W. H. 1968. Field observations on the altitudinal distribution of the side-blotched lizard. Northwest Sci. 42:161-164.

Mentions bitterbrush as a major shrub component below 630 feet elevation on a north facing slope in the Rattlesnake Hills of southeastern Washington. Bitterbrush did not occur at elevations from 630 to 3,450 feet.

ROUGHTON, R. D. 1962. A review of literature on dendrochronology and age determination of woody plants. Colorado Dep. Game and Fish Tech. Bull. 15. Colorado Coop. Wildl. Res. Unit, Fort Collins. 99 p.

Reviews literature on dendrochronological and age determination techniques for three shrubs, including bitterbrush. Over 550 references are reviewed.

ROUGHTON, R. D. 1972. Shrub age structures on a mule deer winter range in Colorado. Ecology 53:615-625.

Shrub age structures were determined by sampling in selected communities and aging individual plants by growth-layer analysis. Prepared specimens of bitterbrush were easily aged by cross-dating xylem growth layers.

RUMSEY, W. B. 1971. Range seedings versus climax vegetation on three sites in Idaho. J. Range Manage. 24:447-450.

On a loamy, 41 to 56 cm precipitation site of the Lantonia soil series, seedlings yielded an average of 4785 kg/ha compared to about 2464 kg/ha on native range. Climax vegetation on this site is dominated by bitterbrush in the shrub layer.

RUPP, M. S. 1970. Root distribution of *Artemisia tridentata* and *Purshia tridentata* in sandy soils of south-central Washington. Diss. Abs. 30:3052B.

Radioactive I^{131} was injected into the soil to measure and delineate root systems of bitterbrush, big sagebrush, and Sandberg bluegrass.

SABINSKE, D. W., and D. H. KNIGHT. 1978. Variation within the sagebrush vegetation of Grand Teton National Park, Wyoming. Northwest Sci. 52:195-204.

In one of four described communities, bitterbrush occurs with big sagebrush. It was suggested that bitterbrush is able to grow with big sagebrush where silt decreases and sand increases at the 10 to 20 cm soil depth.

SERGURA-BUSTAMANTE, M. 1970. Ecology of bitterbrush (*Purshia tridentata* (Pursh) DC.) in the Silver Lake deer winter range, Oregon. Diss. Abs. 30:4459B-4460B.

Analysis of six plant communities, four of which contained bitterbrush, showed that the occurrence of bitterbrush was not affected by elevation and that it occurred on slopes but not at the tops or bottoms of slopes, or on flat lands. Bitterbrush was absent from soils with a high content of surface gravel, and with high pH and exchangeable sodium. (see also SEGURA-BUSTAMANTE, M. 1970. Ecology of bitterbrush (*Purshia tridentata* (Pursh) DC.) in the Silver Lake deer winter range, Oregon. PhD Thesis. Oregon State Univ., Corvallis. 269 p.)

SHERMAN, R. J., and W. W. CHILCOTE. 1972. Spatial and chronological patterns of *Purshia tridentata* as influenced by *Pinus ponderosa*. Ecology 53:294-298.

In central Oregon pine forests, bitterbrush reproduces almost exclusively from seed and frequently from caches of seed made by rodents. Fire exclusion has caused a decrease in suitable litter-free sites for seed caches and may result in a decline of bitterbrush. Bitterbrush is not fire resistant but is fire dependent.

SILVESTER, W. B. 1976. Ecological and economic significance of the non-legume symbioses. *In:* W. E. Newton and C. J. Nyman (Eds). Proc. First Internat. Symp. on Nitrogen Fixation. Washington State Univ. Press, Pullman. p. 489-506.

Nitrogen fixation by non-leguminous plants, including bitterbrush, is discussed.

SILVESTER, W. B. 1977. Dinitrogen fixation by plant associations excluding legumes. *In:* R. W. F. Hardy and A. H. Gibson (Eds). A treatise on dinitrogen fixation. Section 4, Agronomy and Ecology. John Wiley & Sons, New York, p. 141-190.

The ecological importance of nitrogen fixation by non-leguminous plants, including bitterbrush, is reviewed.

SNEVA, F. A., and D. N. HYDER. 1966. Control of big sagebrush associated with bitterbrush in ponderosa pine. J. Forest. 64:677-680.

A mixed stand of big sagebrush and bitterbrush was sprayed with 2 lb/A of 2,4-D on five dates over three years. May treatments, when Sandberg bluegrass heads were in late boot, resulted in 95 percent sagebrush mortality and 10 percent bitterbrush mortality. Bitterbrush crown area was reduced by 25 percent. After flower eruption, bitterbrush damage increased. Since all bitterbrush leaves were killed at each spray date, recovery was directly related to earliness of spraying and length of growing season remaining after spraying.

STARK, N. 1966. Review of highway planting information appropriate to Nevada. Desert Research Institute. Univ. Nevada, Reno. p. 54.

Summarizes available information applicable to planting bitterbrush on roadsides in Nevada.

STELZER, M. J. 1968. The Great Basin tent caterpillar in New Mexico: life history, parasites, disease, and defoliation. USDA Forest Serv. Res. Pap. RM-39. Rocky Mountain Forest and Range Ext. Sta., Fort Collins. 16 p.

At elevations above 8,000 feet, quaking aspen is the favored host of the caterpillar. Between 1,800 and 3,500 feet, infestations are most serious on cottonwood and willow. Mentions 11 other trees and shrubs, including bitterbrush, on which the caterpillar feeds.

STEWART, W. D. P. 1967. Nitrogen-fixing plants. Science 158:1426-1432.

Discusses the role of bacteria, blue-green algae, root-nodulated angiosperms, and root-nodulated gymnosperms in nitrogen fixation. Notes that nitrogen fixing angiosperms are characteristic pioneer plants of areas low in combined nitrogen and therefore these plants have a competitive advantage. Includes *Purschia [Purshia]* as a root-nodulated angiosperm that needs to be tested for nitrogen fixation.

STUTH, J. W. 1975. Livestock, deer, and logging interactions in the lodgepole pine-pumice region of central Oregon. Diss. Abs. 36:1995-1996.

Bitterbrush was the only species utilized by deer in both logged and non-logged areas. Utilization was least in July and increased on logged areas during August. Overall utilization was seven to ten times higher on logged than on non-logged areas. Cattle use of bitterbrush on fringes of non-logged areas increased during August and reached 75 percent of the diet by the end of the grazing season. Sheep used bitterbrush on both logged and non-logged areas. Logging decreased numbers of bitterbrush plants but yields were 287 to 397 lbs/A on logged vs. 223 to 297 lbs/A on non-logged areas. (see also: STUTH, J. W. 1975. Livestock, deer, and logging interactions in the lodgepole pine-pumice region of central Oregon. PhD Thesis. Oregon State Univ., Corvallis. 175 p.)

STUTH, J. W., and A. H. WINWARD. 1976. Logging impacts on bitterbrush in the lodgepole pine-pumice region of central Oregon. J. Range Manage. 29:453-456.

Production of bitterbrush in logged areas was approximately the same or greater than in adjacent non-logged areas even though an average of 43 percent of the bitterbrush plants were lost during logging. Plants in logged areas had leader growth, 2.5 cm longer, than in non-logged areas. Plants taller than 40 cm were most frequently damaged by logging, and plants 20 to 40 cm tall accounted for the greater production response following logging.

STUTH, J. W., and A. H. WINWARD. 1977. Livestock-deer relations in the lodgepole pine-pumice region of central Oregon. J. Range Manage. 30:110-116.

Bitterbrush gradually replaced maturing forbs in the diets of deer during July. Bitterbrush was the most important forage species in the diets of cattle, sheep, and deer using the lodgepole pine/bitterbrush/western needlegrass communities. Fall was the peak consumption period for bitterbrush by cattle and deer, while sheep consumed large quantities throughout the summer grazing season.

STUTZ, H. C. 1972. Genetic improvement in crop species as contrasted with possibilities in shrubs. *In:* C. M. McKell, J. P. Blaisdell, and J. R. Goodin (Eds). Wildland shrubs—their biology and utilization. USDA Forest Serv. Gen. Tech. Rep. INT-1. Intermountain Forest and Range Exp. Sta., Ogden. p. 139-143.

Although bitterbrush and Stansbury cliffrose cross freely, at least 23 different characteristics distinguish these two species. So common is the hybridization and backcrossing that essentially no population of bitterbrush in Utah is free of introgression from cliffrose. Only two recombination products of crossing have found adaptive environmental niches.

STUTZ, H. C. 1974. Rapid evolution in western shrubs. Utah Sci. 35:16-20, 33.

Describes the sexual recombination process responsible for generation of new species. Although cliffrose and bitterbrush belong to separate genera, they hybridize quite commonly in nature, producing a highly fertile hybrid. It was suggested that the lower palatability of cliffrose to sheep creates an intense, selective advantage and allows cliffrose to spread its genes northward into bitterbrush populations.

STUTZ, H. C., and L. K. THOMAS. 1964. Hybridization and introgression in *Cowania* and *Purshia*. Evolution 18: 183-195.

Describes crossing strategies between two distinct genera and suggests that desert bitterbrush (*Purshia glandulosa*) is a stabilized segregant from the hybridization product of Stansbury cliffrose (*Cowania stansburiana*) and antelope bitterbrush (*P. tridentata*).

THORNTON, J. F. 1960. Managing Great Basin juniper-sage-bitterbrush rangelands for big game and livestock on national forests in California. Amer. Soc. Range Manage. Abs. 13:59.

Forage management on juniper-sagebrush-bitterbrush range should include both livestock and game. Competition for bitterbrush can be minimized by grazing sheep in the spring and leaving most of the season's growth for deer.

TIEDEMANN, A. R., G. O. KLOCK, L. L. MASON, and D. E. SEARS. 1976. Shrub plantings for erosion control in eastern Washington—progress and research needs. USDA Forest Serv. Res. Note PNW-279. Pacific Northwest Forest and Range Exp. Sta., Portland. 11 p.

Bitterbrush seedlings were planted on two forest sites in eastern Washington on colluvial subsoil from granodiorite parent material. Other soils were decomposed granodiorite, volcanic ash, and "popcorn" pumice. Organic matter content was low and slopes ranged from 40 to over 70 percent. Bitterbrush survival appeared to be affected by elevation differences between source and planting site. Seedling size at planting time should be tall enough to withstand inundation by ravelling, loose soil material, yet the root system should be small enough to allow hand planting with minimum site disturbance.

TINGEY, W. M., C. D. JORGENSEN, and N. C. FRISCHKNECHT. 1972. Thrips of the sagebrush-grass range community in west-central Utah. J. Range Manage. 25:304-308.

Four bitterbrush sites in Tooele County, Utah, yielded three species of thrips feeding on bitterbrush litter. These three species were found feeding on foliage of other plant species however, and one species—*Frankliniella occidentalis* (Pergande)—was considered a potential pest on rangelands.

TRLICA, M. J., M. BUWAI, and J. W. MENKE. 1977. Effects of rest following defoliations on the recovery of several range species. J. Range Manage. 30:21-27.

Following 90 percent defoliation, bitterbrush made good recovery after 14 to 26 months rest. Heavy defoliation during the fruit development stage resulted in shorter twigs than plants defoliated at other stages. A rest period of 14 to 26 months was not sufficient for complete recovery of vigor, herbage yield, and total nonstructural carbohydrates. Live crown cover following rest was less than control plants if bitterbrush had been defoliated at any of four phenological stages. Defoliation at the fruit development or seed shatter stages was most harmful.

U.S. FOREST SERVICE. 1976. Some important native shrubs of the West. USDA. Forest Service. Intermountain Forest and Range Exp. Sta., Ogden. 16 p.

Fourteen native shrubs, including bitterbrush, are described and illustrated with emphasis on their position in the plant community, their value on wildlands, and their cultivation and potential for future use.

URNESS, R. J., A. D. SMITH, and R. K. WATKINS. 1977. Comparison of *in vivo* and *in vitro* dry matter digestibility of mule deer forages. J. Range Manage. 30:119-121.

Percent digestibility using *in vivo* and *in vitro* techniques was lower for bitterbrush than most other shrubs tested. *In vivo* results were higher than those from *in vitro* methods.

WALLMO, O. C., L. H. CARPENTER, W. L. REGELIN, R. B. GILL, and D. L. BAKER. 1977. Evaluation of deer habitat on a nutritional basis. J. Range Manage. 30:122-127.

Average winter cellulose content of several shrubs, including bitterbrush, was 19 to 32 percent. Lignin content was 18 to 25 percent. Average digestibility of twigs in February was 34 percent.

WARD, A. L. 1971. *In vitro* digestibility of elk winter forage in southern Wyoming. J. Wildl. Manage. 35:681-688.

Rumen fluid from elk and cattle was used to determine *in vitro* dry matter digestibility of dried forage samples collected from November through March. Bitterbrush digestibility using elk inoculum was 23.3 to 30.3 percent and using inoculum from a steer on a lucerne diet was 22.2 to 24.7 percent. Digestibility values were highest in the March samples.

WARING, R. H. 1969. Forest plants of the eastern Siskiyous: their environmental and vegetation distribution. Northwest Sci. 43:1-17.

In the eastern Siskiyou Mountains of southern Oregon and northern California, Jeffrey pine occurs on extremely infertile soils derived from perodotite or serpentinite. These soils are high in iron and magnesium and low in phosphorus, potassium, nitrogen, and calcium. These soils are also shallow and generally droughty. Bitterbrush occurs infrequently on rocky sites within the Jeffrey pine type.

WEBSTER, S. R., C. T. YOUNGBERG, and A. G. WOLLUM. 1967. Fixation of nitrogen by bitterbrush (*Purshia tridentata* (Pursh) DC.). Nature 216:392-393.

Four-month-old bitterbrush seedlings grown in a sandy soil with high natural nodulation potential were separated from nodules and the nodules were exposed to N^{15}. Using 0.02 atmospheric percent of

excess N^{15} as positive evidence of nitrogen fixation, all samples resulted in 0.051 percent or greater.

WEST, N. E. 1968. Rodent-influenced establishment of ponderosa pine and bitterbrush seedlings in central Oregon. Ecology 49:1009-1011.

In montane forests of central Oregon, about 90 percent of bitterbrush seedlings develop in clusters. Clusters originate from unrecovered caches of seed made by small rodents.

WRIGHT, H. A. 1972. Shrub response to fire. *In:* C. M. McKell, J. P. Blaisdell, and J. R. Goodin (Eds). Wildland shrubs—their biology and utilization. USDA Forest Serv. Gen. Tech. Rep. INT-1. Intermountain Forest and Range Exp. Sta., Ogden. p. 204-207.

Reviews literature on effects of fire on several plants including bitterbrush.

WRIGHT, H. A. 1978. The effect of fire on vegetation in ponderosa pine forests. Texas Tech. Univ., Range and Wildl. Info. Series No. 2, College of Agri. Sciences Pub. T-9-199. Texas Tech Univ., Lubbock. 21 p.

A state-of-the-art review of fire effects on plants is presented, including bitterbrush, in five climax and four seral ponderosa pine communities.

WRIGHT, H. A., and C. M. BRITTON. 1976. Fire effects on vegetation in western rangeland communities. *In:* Use of prescribed burning in western woodland and range ecosystems Symp. Proc. Utah Agr. Exp. Sta., Logan. p. 35-41.

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