GUIDELINES FOR VEGETATION SAMPLING

Montana Department of Environmental Quality

Permitting and Compliance Division

Industrial and Energy Minerals Bureau

Coal and Uranium Program

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ACKNOWLEDGEMENTS

This document originally included sections on technical vegetation standards, normal husbandry practices, and a host of other pertinent subjects. It was authored by Dave Clark in the late 1990's while he served as the Coal Program vegetation ecologist. Dave subsequently moved on to New Mexico's coal program. In 2003 the Montana State Legislature enacted a significant rewrite of the Montana Surface and Underground Mining Reclamation Act (MSUMRA), resulting in substantial rule changes in 2004.

As a result of the changes in the law and rules, many of the specifications and requirements in the original document no longer applied. The basic approach to reclamation and bond release changed from one focused on vegetation to one focused on post-mining land use, and requirements for monitoring had changed. Many of the rules cited had been repealed and much of the numbering had been changed. In addition, the Office of Surface Mining had dropped its requirement to approve the states' vegetation guidelines, but not the list of normal husbandry practices.

These changes necessitated wholesale rewrites of the technical standards and normal husbandry sections, which have been put into separate documents. However, the sampling guidelines were still quite applicable; for the most part, they needed only reworking to conform to the new rule numbers.

Shannon Downey completed the rewrites to this document, and any errors contained in this version are likely the result of mistakes made in eliminating references to repealed rules or making corrections to conform to changes. The treatise on sampling that Dave originally produced is clear, concise, and rigorous, with a good bit of statistical elegance. His contribution to Montana and the general reclamation community is heartily acknowledged.

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INTRODUCTION

The Administrative Rules of Montana (ARM) at 17.24.726(1) require the Department to supply guidelines which describe acceptable field and laboratory methods to be used when collecting and analyzing vegetation production, cover, and density data. The following information addresses this requirement. Additional guidelines regarding the use of reference areas and a framework for technical vegetation standards can be found in another document. Approved normal husbandry practices are discussed in a third document.

Appendix A provides formulas, examples, references, and tables for use in sample adequacy and bond release evaluations. Appendix B is a listing of vegetation and land use rules that should be reviewed for compliance. Appendix C is a copy of *Montana Range Plants*, by Dr. Carl Wambolt, which was published in 1981 as Montana State University Cooperative Extension Service Bulletin 355, and is reproduced here by permission of the Extension Service. The bulletin characterizes the longevity, origin, season of growth, and response to cattle grazing of most Montana range plants, and is suggested as a classification standard for vegetation inventories.

Please read these guidelines carefully and completely prior to initiating any vegetation inventories or analyses. A preliminary meeting and site reconnaissance with Department staff is strongly recommended, as is the submittal of a plan of study to ensure that all relevant rules will be efficiently addressed.

The Department has sought to ensure that each of the methods recommended and approved in these guidelines is technically sound and unambiguous. Methods other than those presented here certainly exist and may be acceptable. The use of procedures or practices that are not included in these guidelines, however, requires prior approval of both the Department and the Office of Surface Mining (30 CFR 732.17 and 816.116). Alternative methods that are contained in active mining permits have already received state and federal approval.

SAMPLING METHODS [ARM 17.24.304 AND 726]

The field and laboratory methods described below are approved for use during vegetation baseline, reference area inventories, and Phase III bond release evaluations. Sample adequacy must be attained for total production, total live cover, and woody-taxa density estimates of each plant community during all inventories and bond release evaluations (see the Sample Adequacy discussion in Appendix A). Appropriate sample sizes for other specialized monitoring (e.g., status of threatened and endangered species) will be determined on a case-by-case basis, depending on the specific purposes and the vegetation attributes for each monitoring.

Periodic revegetation monitoring, as per ARM 17.24.723, is not required to follow these parameters. Such monitoring should be designed to facilitate management needs during the responsibility period and to confirm that the community development of reclaimed vegetation is tracking toward the Phase III success standards.

All technical data submitted shall include the name and affiliation of the principal investigator, the dates of data collection, a description of the methods used, and listings of all references used and consultations conducted during the study. Raw vegetation data in an electronic spreadsheet format and map data in a digital format shall be submitted to the Department. Consult with the Department concerning software compatibility.

The Department recognizes that each sampling method has inherent strengths and weaknesses. The Department strongly encourages all companies select methods that are best suited for meeting defined monitoring goals, while taking advantage of the methods strengths and minimizing the affects of the weaknesses. To help insure that valid methods are used and appropriately applied and that the data collected for the various analyses are reliable, applicants and permittees must submit a QA/QC plan for review and approval by the Department prior to initiation of vegetation monitoring.

Upon implementation of specific vegetation monitoring methods, the Department strongly encourages the operators to maintain, to the extent possible, the same investigators for the duration of the project (not only annually, but year to year). Due to the importance of this issue in providing sampling consistency etc., the issue must be addressed in the QA/QC plan. For purposes of comparison, the data from reclaimed and reference areas must be collected during the same time period to ensure that vegetative growth is similar in the two areas. To provide for better year to year comparison, data should be collected during the same vegetative growth period each year. This consistency should reduce sampling variability and increase data quality. The Department will make regular field inspections during the sampling process to assess the field application of the sampling method and the quality of the data being collected. Changes to the sampling methods may be recommended or required based on the results of the field review.

2.1 ECOLOGICAL SITE AND VEGETATION COMMUNITY DESCRIPTIONS

An ecological or range site map for the permit area at a scale of 1": 400' shall be prepared on a pre-mine topography base. The ecological site map shall be based upon USDA Natural Resources Conservation Service (NRCS) soil survey data and the Ecological Site Descriptions, plus any additional permit-area soil survey work required by the Department. Mapped polygons shall identify the soil groups and extant range conditions, consistent with NRCS guidelines (except that percent relative cover may be used as a measure of species' importance, in lieu of percent air-dry weight). Be sure to cite which version of the NRCS guidelines is used, and use that version consistently. It is recommended that mapped pre-mine land use information [required by ARM 17.24.304(1)(l)] be included on the ecological site map.

A vegetation community map for the permit area, and if proposed, any outlying reference areas, shall be prepared at a scale of 1":400' on a pre-mine topography base. Based on a review of the range and soil maps, aerial photographs, USGS orthophoto quads, and a reconnaissance of the permit area, preliminary physiognomic type and/or community polygons shall be delineated. A stratified random sampling scheme based on the preliminary polygons shall be designed for the collection of production, cover, and density data.

Refinements to community boundaries and designations, and consequent adjustments to the sampling scheme, will undoubtedly be necessary as sampling progresses. A gridded overlay and random numbers table carried in the field may facilitate placement of additional sampling locations in an unbiased manner. Permit-area and disturbance-area boundaries shall be delineated on the vegetation map, as well as reference area locations and boundaries. All sample locations shall be indicated on the vegetation map. All discovered locations of any listed or proposed threatened or endangered plant species shall be identified on the vegetation map.

A narrative description of each vegetation type shall be submitted, listing associated species and discussing the environmental factors controlling or limiting the distribution of species. Current condition and trend shall be described for each community and any significant variants of a community. Individual plot or transect data (either as spreadsheets or field sheets) shall be submitted, as well as summary tables. The following information and site attributes shall be reported for each sample location, as well as for sites which provide habitat for listed or proposed threatened or endangered plant species: date, personnel, aspect, percent slope, topography (ridge, upper slope, midslope, bench, lower slope, toeslope, swale, bottom), configuration (convex, concave, straight, undulating), and a brief description of the substrate. Record incidental vegetation species which are observed adjacent to sample locations or while traveling between locations. A table of the permit-area and disturbance-area acreage of each vegetation community shall be submitted.

Applicants shall submit a list of the scientific names of all vascular plant species observed in each vegetation community (baseline inventories) and revegetation/ physiognomic type (bond release evaluations). The USDA NRCS PLANTS Database is the preferred reference for nomenclature.

2.2 ANNUAL PRODUCTION

Production sampling shall be conducted as near to mid-July as possible, to accurately estimate peak standing crop in our area. Production standards are based on total herbaceous production. Samples need not be segregated by functional group or species, although segregating at least a subsample of the quadrats would facilitate an accurate determination of range condition during baseline and reference area sampling, and is advised.

The clipping of vegetation within 0.5 m^2 quadrats has become the standard method of estimating herbaceous production on Montana coal mines, although the use of quadrats ranging in size from 0.1 m^2 (in very dense grasslands) to 1.0 m^2 (in sparsely vegetated sites) may be acceptable, in consultation with the Department. If livestock grazing is anticipated prior to sampling, production sample sites may need to be located and adequately protected (caged) before grazing begins. Live herbaceous vegetation shall be clipped to ground (or caudex/root crown) level, bagged, and dried to constant weight. Either air-drying or oven-drying may be used, but the drying method must be specified and applied consistently to all samples (oven-dried weights often average 10% less than air-dried weights). Sample weights shall be reported as grams/m^2, and class productivity as pounds/acre. If kilograms/ha is reported, **the converted value for pounds/acre *must also be reported*.**

ARM 17.24.301(61)(d) defines commercial forest land as acreage which produces or can be managed to produce in excess of 20 cubic feet per acre per year of industrial wood. ARM 17.24.304(1)(l)(ii) requires an analysis of the average yield of wood products from such lands. Thus, an estimate of timber production must be made for forested acreage that is proposed for disturbance. In eastern Montana, ponderosa pine savannahs (i.e., grasslands with scattered trees, but less than 25% tree canopy coverage) are not expected to yield wood products in excess of 20 ft^3/ac/yr (Pfister et al. 1977, B. Dillon, DNRC forester--pers. comm.). Therefore, annual wood production need only be calculated for ponderosa pine-dominated communities having 25% or greater pine canopy coverage. Yield capability data from similar sites may be cited if available from the USDA Forest Service or the Montana Department of Natural Resources and Conservation. If such data are not available, the following procedure may be used to estimate wood product annual production and tree density.

Estimate basal area (square feet of wood) per acre from a minimum of three randomly located sample points for each pine-dominated community up to 10 acres in size; add an additional sample point for each additional 10 acres of that community, or portion thereof. A Relaskop, angle-gauge, or prism may be used to determine sample trees by the Bitterlich variable-radius method (Chambers and Brown 1983). Select a basal area factor (BAF) and corresponding sighting angle that will result in 5-15 trees being sampled at each sample point (a BAF of 10 is generally appropriate for eastern Montana ponderosa pine stands). The diameter at breast height (DBH), age, and height of the sample trees are measured, and the trees are assigned to 4" DBH size classes (e.g., 0-4", 4-8", 8-12", 12-16", 16-20", and 20"+).

Tree heights may be measured by reading the T scale of the Relaskop at a distance of 66 feet from the tree or by reading the tangent of angles from the percent scale of instruments like the Abney level or Sunnto level. Tree ages shall be measured by counting annual rings of increment cores. Age need only be measured for one tree (the first encountered) in each DBH size class at each sampling location. Add 10 years to the ring count if boring at breast height, to account for seedling growth to that height (B. Dillon--pers. comm.) or bore as near to the ground as possible. Age may be estimated by a whorl count on smaller trees.

If a density estimate is being made for all trees, the basal area of junipers and deciduous trees may be calculated in a similar manner, grouping the trees into 4" DBH size classes by species. Heights and ages are not required for non-timber species.

For each DBH size class, calculate

1. mean basal area/tree = 0.005454 (mean DBH^2)

2. mean basal area/acre = total number of trees sampled/number of sample points x BAF

3. number of trees/acre = $\dfrac{\text{mean basal area/acre}}{\text{mean basal area/tree}}$

4. volume/acre/year = mean basal area/acre x mean tree height/mean tree age

(DBHs are in inches, heights are in ft., basal areas are in square ft., and volumes are in cubic ft.)

Sum the volume/acre/year estimates from each of the DBH size classes and reduce the sum by 25% to account for yield losses due to log taper, bark, and defects (B. Dillon--pers. comm.), thus obtaining the final estimate of the yield capability (annual production) for each ponderosa pine-dominated community. For each tree species, sum the number of trees/acre for each size class to estimate density.

2.3 COVER

Percent cover for bare ground, rock, litter, lichens, moss, and each vascular plant species shall be recorded. Cover subtotals shall be calculated for each native and introduced functional group, and total live vegetation cover shall be reported. Relative cover of functional groups shall also be calculated and reported. Relative cover, frequency, and constancy of species' occurrence may be reported in summary tables, but are not required.

Cover measurements may be made by point intercept, line intercept, line point, or ocular estimation. No matter which method is selected, special care must be taken to obtain an accurate estimate for species with relative cover near 1%.

The **point intercept method**, as originally conceived by Levy and Madden (1933), involves dropping a series of pointed pins (usually 10) through a frame and recording the nature of the cover touched by each pin. More recently, the method has been modified to include the use of cross-hairs within low-magnification sighting tubes and laser light beams, rather than pins, to indicate sampling points along a transect. Each randomly located frame or transect constitutes one sampling unit.

The **line intercept method** (Canfield 1941) is conducted by laying out a measuring tape along a randomly-selected bearing and summing the lengths intercepted by each species' canopy. Considerable overlap of species cover occurs when the line intercept method is used on moderately- to densely-vegetated stands. Under such field conditions the method can be quite time-consuming, and in consequence it has only rarely been used on Montana coal mines. The line intercept method is most efficient as a means of estimating either shrub or low, sparse herbaceous cover. Each randomly located transect represents one sampling unit.

The **line point method** (Heady et al. 1959) is a sort of hybrid of the point intercept and line intercept methods. It is implemented by laying out a measuring tape along a randomly selected bearing and recording the nature of the cover at several (usually 100) points along the tape. Each randomly located transect represents one sample unit. Herrick et al (2005) provide an updated version of the line-point intercept method, along with data forms.

If Daubenmire's (1959) **ocular estimation method** is used, the procedure should be modified so that absolute cover is estimated to the nearest percent. However, if the use of Daubenmire's (or smaller) coverage classes has previously been approved, such use may be continued for the sake of consistency. Acceptable quadrat sizes are not fixed and will vary depending on the vegetation characteristics and the experience of the investigators; sample quadrats ranging in size from 0.1 to 0.5m^2 (and sometimes larger) have been approved for use on Montana coal mines. Each randomly located transect with 10 systematically placed quadrats represents one sampling unit.

2.4 DENSITY

When comparing the stocking rates of revegetated areas with reference areas or historic record technical standards, only living, healthy plants may be counted. Countable trees, shrubs and half-shrubs on revegetation must be at least 2 years old.

Shrub and half-shrub densities have been measured on Montana coal mines by direct counts within rectangular or circular plots or belt transects, and in a few cases where the inventory areas were small or woody taxa had low densities, by total counts. Plot or belt transect dimensions are not fixed and may be selected in accordance with site and vegetation characteristics; plots and belt transects ranging in size from 10m^2 to 100m^2 have been approved for use. The total number of stems per quadrat and a calculated estimate of the number of stems per acre for each woody species shall be reported.

Tree densities may be estimated by counts within 0.1-acre circular plots (radius = 11.35m or 37.24ft), or by the Bitterlich variable-radius method previously described for estimating timber production. Tree density in savannah communities may also be measured by counts from aerial photographs. Lindsey et al. (1958) assessed the efficiency of various plot-based and plotless sampling techniques for measuring both density and basal area in forests. They took into account the time required for sampling sufficient units to attain a standard error of 15% of the mean, as well as the time spent moving between sampling sites. It was concluded that the Bitterlich variable-radius method was most efficient if basal area was important, and that a 0.1-acre circular plot was the most efficient method if only density data were required.

2.5 UTILITY

A map and supporting narrative description of the pre-mine condition, capability, and productivity within the proposed permit area are required. If the pre-mine land use was changed within five years of the anticipated date of commencement of mining operations, then the historic land use shall also be described. Land use capability must be analyzed in conjunction with the baseline climate, topography, geology, hydrology, soils, and vegetation information. The productivity of the proposed permit area shall be described in terms of the average yield of food, fiber, forage, or wood products obtained from such lands under high levels of management. Productivity may be determined by site-specific yield data or estimates for similar sites based on data from federal or state agencies, or state universities.

For the purpose of bond release, utility need not be demonstrated for any lands disturbed after May 3, 1978. For bond release on lands where all disturbance occurred prior to this date see the discussion at 3.8 in the Framework for Technical Vegetation Standards. Demonstrating utility for livestock is one of the methods for showing eligibility for Phase III bond release on these lands. Average weight gain per day or average gain per acre are excellent integrated measurements of livestock production capability in response to the quantity and quality of both forage and water. Alternatively, showing AUM's of grazing per acre, combined with percent utilization data (or pounds per acre of residual vegetation), is also an acceptable method for demonstrating livestock utility.

PHASE III BOND RELEASE EVALUATIONS

3.1 HYPOTHESIS TESTING FOR PRODUCTION, COVER, AND DENSITY [ARM 17.24.726]

Population parameters which must be statistically tested are total production, total cover, and woody-plant density. The hypotheses which are tested during Phase III bond release evaluations are: (1) the null hypothesis, that the parameter mean of the revegetated area is less than 90% of the parameter mean of the reference area, vs. (2) the alternative hypothesis, that the parameter mean of the revegetated area is greater than or equal to 90% of the parameter mean of the reference area (Ames 1993):

(1) $H_o : \mu_{revegetation} < 0.9\ \mu_{reference\ area}$

(2) $H_a : \mu_{revegetation} \geq 0.9\ \mu_{reference\ area}$

Note that the above formulation of the null hypothesis is different than the classical null hypothesis that is applied to experimental analyses. In the classical case, a hypothesis of no effect is assumed until convincing evidence of the high probability of an experimental effect has been acquired. However, the classical null hypothesis is inappropriate when applied to surface disturbances, where there is no question that an effect has occurred. The appropriate question is whether or not the performance standards required by regulation have been achieved (Erickson 1992, Erickson and McDonald 1995).

The so-called reverse null hypothesis, as presented above, is more than just theoretically correct. Inadequacies and difficulties that are encountered when the classical null hypothesis is misapplied become moot when the null hypothesis is correctly formulated. For example, under the classical null hypothesis, it would be to a company's advantage to collect few samples with high variance and poor quality control, in order to minimize the power of the test and thus the chance of rejecting the assumption of "no effect". Companies taking more samples and practicing better quality control may be at a disadvantage by having greater power to detect a statistically significant difference between reclamation and the performance standard. The Department would have to counteract these basic flaws with a web of regulations designed to control both the precision and the power of hypothesis tests, under all conceivable circumstances.

The classical null hypothesis approach may be used, however, if this route is chosen, it is incumbent on the operator to unequivocally demonstrate sample adequacy. Sample-size equations have been derived for populations which are normally distributed, but when such equations are used with data that are not normally distributed or not evenly dispersed, as is often true with biological populations, the calculated sample sizes may be unreasonably large. Likewise, if a preliminary sample is too small to contain much information, even data from normally distributed populations may result in sample-size overestimates (see the Sample Adequacy discussion in Appendix A). An arbitrary maximum sample size must be negotiated, and the degree of sampling effort expended may be more dependent on the skill of each side's negotiators than on the characteristics of the vegetation.

Under the reverse null hypothesis, however, if the performance standard has not been achieved there is no sample size that will indicate otherwise (McDonald and Erickson 1994). Small sample sizes and poor quality and variance control practices will not enhance the operator's chances for bond release. Therefore, when conducting Phase III bond release evaluations using the reverse null hypothesis the operator may select the number of samples to be collected, and the Department's responsibility will be to ensure that the data are randomly selected and properly stratified (that is, ***the data must be unbiased observations from the populations for which inferences are being made***). The most important consideration to remember about random sampling is that all locations within the population of interest must have an equal probability of being included in a sample.

For the sake of guidance, the Department recommends a minimum sample size of 30 for each population, and population parameter, to be tested. This is the approximate minimum sample size necessary to invoke the central limit theorem, which holds that even if the original population is not normally distributed, the standardized sample mean is approximately normal if the sample size is reasonably large. The central limit theorem thus validates the use of parametric procedures no matter what distribution the original population may have (Snedecor and Cochran 1980, pp. 45-50). Parametric procedures are generally more powerful than their nonparametric equivalents, and using parametric tests should improve an operator's ability to reject the null hypothesis if the performance standard has been achieved.

Data transformation may effectively increase the power of a hypothesis test. If a test statistic for untransformed data fails to indicate that the performance standard has been achieved, it would be advisable to apply one or more of the transformations discussed in Appendix A to the data and re-test.

The arcsine transformation is used to approximate the normal distribution for percentages (such as percent cover) which naturally form binomial distributions when there are two possible outcomes (i.e., live cover either is or is not hit). If percentages range from about 30 to 70%, as is typical with Montana vegetation cover data, there is no need for transformation. If many values are nearer to 0 or 100%, however, the arcsine transformation (described in Appendix A) should be used.

Equal sample sizes should be collected whenever two or more populations are being compared. Parametric tests are not seriously affected by unequal sample variances when sample sizes are equal, but the combination of unequal variance and unequal sample size may result in a higher Type I error rate than is specified by the α level of the test (Neter, et al. 1985, p. 624). By rule, the level of the test must be held at $\alpha = 0.10$. The Satterthwaite correction, discussed in Appendix A, provides another means of ensuring that the specified α level is maintained.

When comparing the total live cover of two populations, most operators separately tally first-hit (top-layer, non-stratified, without-overlap) cover and multiple-hit (all-layer, stratified, with-overlap) cover. If first-hit cover tends to maximize at 100% (for example, when evaluating special use pastures), then the multiple-hit cover should be compared in order to better approximate the normal distribution. Since the normal distribution is an additive model, adding cover strata together to approximate the model is legitimate.

Naturally, the methods and personnel used to estimate total live cover must be exactly the same whenever samples from two populations are going to be compared.

Production sampling must be conducted as near to mid-July as possible, to accurately estimate peak standing crop in our area. Reference area and reclamation production sampling efforts must not be separated by more than two weeks, to minimize sampling bias.

In consideration of the above discussion, the Department recommends the following hypothesis-testing procedures:

1. Design a study and submit the plan to the Department for review, to ensure that all relevant rules will be addressed.

2. Collect the data, and check for normality (that is, symmetry about the mean). Histograms or the distribution plot functions found in any statistical software package are adequate for determining whether the sample distribution is approximately normal.

3. If two populations are being compared, the assumption of equal variances should be verified by Levene's test (Appendix A).

4. Choose the appropriate procedure as described below, based upon the preliminary test results. The nonparametric tests (i.e., sign test and Mann-Whitney test) should not be substituted for parametric tests if the data appear to be normally distributed, since the operator's power to reject the null hypothesis will likely be reduced. Appendix A provides statistical formulas, examples, references, and probability tables for each of the approved procedures.

5. Submit a copy of each hypothesis-testing calculation which is conducted in support of an application for bond release.

<table>
<tr><th>Preliminary test results</th><th>Comparing two independent samples</th><th>Comparing to a technical standard</th></tr>
<tr><td>Data are normal
Variances are equal</td><td>Conduct a two-sample t test.</td><td rowspan="3">Conduct a one-sample t test.</td></tr>
<tr><td>Data are normal
Variances are not equal
Sample sizes are equal</td><td>Calculate the Satterthwaite correction and conduct a two-sample t test.</td></tr>
<tr><td>Data are normal
Variances are not equal
Sample sizes are not equal</td><td>Calculate the Satterthwaite correction, or transform the data and test the variances, or collect additional samples. Conduct a two-sample t test.</td></tr>
<tr><td>Data are not normal
Variances are equal</td><td>Conduct a Mann-Whitney test, or transform the data. If the transformed data are approximately normal, conduct a two-sample t test.</td><td rowspan="3">Transform the data; if the transformed data are approximately normal, conduct a one-sample t test; or conduct a one-sample sign test.</td></tr>
<tr><td>Data are not normal
Variances are not equal
Sample sizes are equal</td><td>Transform the data; if the transformed data are approximately normal, conduct a two-sample t test, using the Satterthwaite correction as necessary.</td></tr>
<tr><td>Data are not normal
Variances are not equal
Sample sizes are not equal</td><td>Transform the data or collect additional samples and reassess normality and variance equality. Conduct the Mann-Whitney test, or the two-sample t test and Satterthwaite correction, as appropriate.</td></tr>
</table>

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APPENDIX A

Statistical Formulas, Examples, and References

1. Determining sample adequacy

a. The Cochran formula (parameter estimation)

Sample adequacy must be demonstrated during all vegetation studies. When estimating population parameters, numerical sample adequacy is attained when sufficient observations are taken so that we have 90% confidence that the sample mean lies within 10% of the true population mean. The minimum number of samples required to estimate a parameter with this level of precision is given by the Cochran formula

$$n_{min} = \frac{(t\,s)^2}{(0.10\,\bar{x})^2}$$

where

t	is the tabular t value for a preliminary sample with n-1 degrees of freedom and a two-tailed significance level of $\alpha = 0.10$
s	is the standard deviation of a preliminary sample
$\bar{x}$	is the sample mean of a preliminary sample

Note that the Cochran formula, when modified so that $2(zs)^2$ is the numerator, is frequently cited as the Wyoming DEQ formula. Doubling the minimum sample size in this manner is appropriate when two populations are being compared, but is not correct when inferences are only being made for one population. Further, the t distribution, not the z distribution, should be used when n_{min} is calculated from a preliminary sample (i.e., from experimental data). A two-tailed t value is used, since we wish to control both underestimates and overestimates of the population mean.

Two examples illustrate some properties of the Cochran formula. In the first case, a small preliminary production sample of n = 5 is collected, which yields 0 = 1618 and s = 710. From the two-tailed column of Appendix Table A-1, t with 4 d.f. = 2.132. We calculate

$$n_{min} = \frac{(2.132 \times 710)^2}{(0.10 \times 1618)^2} = 87.5 \text{ samples}$$

In the second case, a more ambitious preliminary sample of n = 15 is collected, yielding 0 = 1524 and s = 267. The tabular *t* value with 14 d.f. = 1.761, and therefore

$$n_{min} = \frac{(1.761 \times 267)^2}{(0.10 \times 1524)^2} = 9.5 \text{ samples}$$

Clearly, the Cochran formula is very sensitive to the preliminary variance estimate, and if the preliminary sample size is small (i.e., if it doesn't include very much information), the variance estimate and n_{min} may be excessively large. On the other hand, if the preliminary sample is reasonably large, the population is properly stratified, and good quality control is practiced, the calculated minimum sample size should not be excessive. It should seldom be necessary to collect more than 30 cover, production, or density samples from any appropriately stratified population.

b. Sample sizes for comparison of means

The comparison of population means with 90% confidence is an inherent property of each of the Phase III bond release testing procedures which are approved in these guidelines. A conclusion that the performance standard has been met will not occur unless 90% confidence is attained. The following table, derived from the relationship

$$n = 2\,(z_{2a} + z_{\exists})^2\, s^2 / d^2 \quad \text{(Snedecor and Cochran 1980, p. 104)}$$

provides an easy means of approximating how many observations will be needed to attain 90% confidence, in consideration of the differences in sample means and the standard deviations found during reference area and/or revegetation monitoring (a more accurate estimate may be obtained by replacing the "generic" *z*-values with *t*-values based on actual preliminary sample sizes). We calculate a standardized difference d/s, where d is the observed difference in the means from preliminary sampling, and s is the standard deviation of the more variable sample. With the probability of both Type I and II errors (α and β, respectively) set at 0.10 for a one-sided test, the number of observations to be collected from <u>each</u> population is

d/s	n	d/s	n	d/s	n	d/s	n
.30	100	.55	30	.80	14	1.1	7
.35	74	.60	25	.85	12	1.2	6
.40	56	.65	21	.90	11	1.3	5
.45	45	.70	18	.95	10	1.4	5
.50	36	.75	16	1.00	9	1.5	4

We can estimate the number of observations needed for a comparison of means with the data from our first example above. Let's say that the data set with n = 5, 0 = 1618, and s = 710 is from reclamation, and the data set with n = 15, 0 = 1524, and s = 267 is from a reference area (this is, in fact, the actual case). We multiply the reference mean by the 90% performance standard and obtain 1371.6. Therefore

$$d = 1618 - 1371.6 = 246.4$$
$$s = 710$$
$$\text{and } d/s = 0.347$$

Interpolating on the table values above, about 76 samples would be needed from each area. If the standard deviation from the larger sample had been the higher variance estimate, then d/s = .923, and 11 samples would be required from each area.

Scrimping on preliminary samples doesn't appear to be a good idea. Base sampling estimates on at least 10 or 15 preliminary observations, and even more if the populations seem highly variable.

References:
Krebs, C. J. 1989. Ecological Methodology. Harper and Row, New York, NY. 654 pp.
Snedecor, G.W., and Cochran, W.G. 1980. Statistical Methods, 7th ed. Iowa State University Press. 507 pp.

2. Levene's test for homogeneity of variances:

Levene's test uses the average of the absolute values of the deviations from the mean within a class

$$3*x_{ij} - \bar{x}_i*/n$$

as a measure of variability, rather than the mean square of the deviations. Since the deviations are not squared, the sensitivity of the test to non-normality in the form of long-tailed distributions is minimized. Such departures from normality are very common in biological data.

Snedecor and Cochran (1980) provide the following example of how Levene's test is applied. The original data (4 random samples drawn from a *t* distribution, and thus of known equal variance) are on the left and the absolute deviations $*x_{ij} - \bar{x}_i*$ are on the right.

	Data for Class				Absolute Deviations from Class Mean			
	1	2	3	4	1	2	3	4
	7.40	8.84	8.09	7.55	0.54	2.08	1.89	0.71
	6.18	6.69	7.96	5.65	0.68	0.07	1.76	1.19
	6.86	7.12	5.31	6.92	0.00	0.36	0.89	0.08
	7.76	7.42	7.39	6.50	0.90	0.66	1.19	0.34
	6.39	6.83	0.51	5.46	0.47	0.07	5.69	1.38
	5.95	5.06	7.84	7.40	0.91	1.70	1.64	0.56
	7.48	5.35	6.28	8.37	0.62	1.40	0.08	1.53
Total	48.02	47.31	43.38	47.85	4.12	6.34	13.14	5.79
Mean	6.86	6.76	6.20	6.84	0.589	0.906	1.877	0.827

An analysis of variance was performed on the mean deviations in the table on the right, using the class means 0.589, 0.906, 1.877, and 0.827 as the estimates of variability within each class. The table below provides the ANOVA.

Source	df	Sum of Squares	Mean Squares	F
Between classes	3	6.773	2.258	2.11
Within classes	24	25.674	1.070	

The F value 2.11 indicates a non-significant $P > 0.10$ with 3 and 24 degrees of freedom, despite the apparent outlier value of 0.51 in the data for class 3. Snedecor and Cochran note that Bartlett's test, which uses the mean square of the deviations (i.e., the sample variance) as the estimate of variability, and is perhaps the most frequently encountered test of variance homogeneity, erroneously rejects the hypothesis of equal population variances for these data.

In our revegetation vs. reference area setting, a t test of 2 independent samples (Procedure #4 below) may be conducted rather than an ANOVA. The 2-tailed probabilities of Appendix Table A-1 may be used to determine whether the hypothesis of equal variability should be rejected. **Note that the decision rules of the 2-sample *t* test must be reversed when conducting Levene's test, since in this case we are not reversing the classical null hypothesis of equal means.**

Reference:

Snedecor, G.W., and Cochran, W.G. 1980. Statistical Methods, 7th ed. Iowa State University Press. 507 pp.

3. The one-sample, one-sided *t* test:

This test is appropriate for comparing a normally-distributed parameter to a technical standard (Neter, et al. 1985). The test statistic is

$$t^* = \frac{\bar{x} - 0.9\,(\text{technical standard})}{\frac{s}{\sqrt{n}}}$$

where

t^*	is the calculated *t*-statistic
$\bar{x}$	is the sample mean
s	is the standard deviation of the sample
n	is the sample size

The α-level of the test is set at 0.10 by regulation, and the decision rules are

If $t^* < t\,(1 - \alpha;\, n - 1)$, conclude failure to meet the performance standard

If $t^* \geq t\,(1 - \alpha;\, n - 1)$, conclude that the performance standard was met

The following example illustrates application of the test. Revegetation cover sampling provides the following statistics: $\bar{x} = 68.2$, s = 17.4, n = 30. Assume a technical standard of 70% total live cover is approved.

$$t^* = \frac{68.2 - 0.9\,(70)}{\frac{17.4}{\sqrt{30}}} = 1.64 \text{ and the one-tail } t\,(.90;29) = 1.31 \text{ from Appendix Table A-1}$$

Therefore, we conclude that the performance standard was met.

Reference:

Neter, J., Wasserman, W., and Kutner, M. H. 1985. Applied Linear Statistical Models, 2nd ed. Irwin Press, Homewood, IL 60430. 1127 pp.

4. The one-sided *t* test for two independent samples:

This test is appropriate for comparing samples from two independent, normally-distributed populations (Neter, et al. 1985). The test statistic is

$$t^* = \frac{\bar{x}_1 - 0.90\ \bar{x}_2}{\sqrt{\left(\frac{SS_1 + SS_2}{n_1 + n_2 - 2}\right)\left(\frac{1}{n_1} + \frac{0.81}{n_2}\right)}}$$

where

t^*	is the calculated *t*-statistic
$\bar{x}_1$	is the reclamation sample mean
$\bar{x}_2$	is the reference area sample mean
SS_1	is the reclamation sum of squared deviations from the mean $\{\varphi\ (x_{1j} - 0_1)^2\}$
SS_2	is the reference area sum of squared deviations from the mean $\{\varphi\ (x_{2j} - 0_2)^2\}$
n_1	is the reclamation sample size
n_2	is the reference area sample size

The α-level of the test is 0.10, and the decision rules are

If $t^* < t(1 - \alpha;\ n_2 - 2)$, conclude failure to meet the performance standard
If $t^* \geq t(1 - \alpha;\ n_2 - 2)$, conclude that the performance standard was met

For example, let's assume reclamation and reference area sampling has provided the following total live cover data:

For reclamation: 50, 42, 46, 48, 63, 46, 48, 42, 50, 42, 54, 52, 35, 45, 52
For the reference area: 49, 51, 53, 47, 55, 54, 44, 47, 50, 47, 52, 40, 56, 25, 33

The summary table is

Reclamation	$n_1 = 15$	$\bar{x}_1 = 47.6$	$SS_1 = 593.4$
Reference Area	$n_2 = 15$	$\bar{x}_2 = 46.9$	$SS_2 = 1021.7$

and

$$t^* = \frac{47.6 - 0.90\,(46.9)}{\sqrt{\left(\frac{593.4\ +\ 1021.7}{15\ +\ 15\ -\ 2}\right)\left(\frac{1}{15} + \frac{.81}{15}\right)}} = 2.323 \text{ and the one-tailed } (0.90;28) = 1.313 \text{ (Appendix Table A-1)}$$

Therefore, we conclude that the performance standard was met.

Reference:

Neter, J., Wasserman, W., and Kutner, M. H. 1985. Applied Linear Statistical Models, 2nd ed. Irwin Press, Homewood, IL 60430. 1127 pp.

5. The one-sample, one-sided sign test:

The sign test is appropriate for comparing a sample with observations which are not normal (i.e., not symmetrical about the mean) to a technical standard (Daniel 1990). Observations must be randomly selected and independent. An early criticism of these guidelines questioned the use of the sign test, rather than the Wilcoxon signed-rank test, when comparing a nonnormal population to a technical standard. The signed-rank is generally the more powerful test, however it carries the assumption that the population being sampled is symmetrical, i.e., that the median is equal to the mean. If the assumption of symmetry is met (or can be met by transforming the data), the Department recommends that the even more powerful one-sample *t* test be used. If the data are not symmetrically distributed, but an obvious majority of the sample values are greater than the performance standard, then the sign test is recommended.

The technical standard is multiplied by the 0.90 performance standard and the result is subtracted from each observation, recording the sign of the difference. Any observations which are equal to 90% of the technical standard, and thus yield no difference, are dropped from the analysis. The test statistic *k* is the number of "minus" signs. K designates a random variable drawn from a binomial distribution, which is the appropriate model for sampling when only 2 outcomes are possible, such as coin tosses, or in this case, plus or minus signs. Since $\alpha = 0.10$ by regulation, the decision rules are

> If P(K $\leq k$, given sample size n from a binomial population expected to yield minus signs 50% of the time if H_o is true) > 0.10, conclude failure to meet the performance standard.
>
> If P(K $\leq k$, given sample size n from a binomial population expected to

yield minus signs 50% of the time if H_o is true) $\leq$ 0.10, conclude that the performance standard was met.

Assume that reclamation sampling has provided the following 26 tree-density observations, which will be compared to a technical standard of 40 trees/acre

30	24	90	0	56	45	39	15	22	45	10	32	30
38	180	36	0	45	15	70	45	67	55	90	78	57

Multiplying the technical standard by the 90% performance standard yields 36. Subtracting 36 from each observation results in the following signs

– – + – + + + – – + – – –
+ + (tie dropped) – + – + + + + + + +

and thus k = 10 minus signs, and n = 25.

From Appendix Table A-2 we determine that P(K $\leq$ 10, given a sample size of 25 and a 50% chance for minus signs if H_o is true) = 0.2122. Therefore, we conclude failure to meet the performance standard. In this example, 8 or fewer minus signs would result in a conclusion that the performance standard had been achieved.

Daniel (1990) provides a large-sample, normal approximation to the binomial

$$z = \frac{(\text{No. of minus signs} + 0.5) - 0.5n}{0.5\sqrt{n}}$$

for sample sizes of 12 or larger.
For the tree-density example given above, the large-sample normal approximation would be applied as follows

$$z = \frac{(10 + 0.5) - 0.5(25)}{0.5\sqrt{25}} = -0.80$$

Appendix Table A-3 indicates that the probability of observing a value of z this small is 0.2119, and as above, we conclude failure to meet the performance standard. **Note that we are determining the probability of observing <u>fewer</u> than the expected value of 50% minus signs. If the number of minus signs exceeds 50% of the total number of observations, there is no need to conduct the sign test--the performance standard has not been met.**

Reference:
Daniel, W.W. 1990. Applied Nonparametric Statistics, 2nd ed. PWS-KENT, Boston. 635 pp.

6. The one-sided Mann-Whitney test for two independent samples:

The Mann-Whitney test is appropriate for testing whether two populations have the same median values for a parameter. The populations need not follow a normal distribution, although it is assumed that the two populations have the same distribution; that is, the population variances are assumed to be equal. The Mann-Whitney test is especially apt in cases where two long-tailed sample distributions are being compared, because comparisons of observation ranks, rather than actual values, are made.

The first consideration in the bond release scenario is how to incorporate the 90% performance standard into the test. We wish to detect a shift in the hypothesized population median, rather than a multiplicative effect. A transformation of both reclaimed and reference data must be made prior to assigning ranks. Since ranks are invariant to logarithmic transformations, the log transformation is an appropriate choice. For the reference area data, the transformation is

$$X'_{reference} = \log(X_{reference} + 1) + \log(0.9)$$

Remember that log (xy) = log (x) + log (y). The 1 is added to the observation values in case some observations are equal to zero, since log (0) is undefined. The reclamation data is transformed as shown

$$X'_{reclamation} = \log(X_{reclamation} + 1)$$

We then combine all of the log-transformed values from both samples and rank them from the smallest (which is given a rank of 1) to the largest. Tied observations are assigned the average of the ranks they would have received if there were no ties. We then sum the ranks of the transformed observations from the reference area population ($S_{reference}$). The test statistic *T* is calculated as follows

$$T = (S_{reference}) - \left(\frac{n_1(n_1 + 1)}{2} \right)$$

where n_1 is the number of observations in the reference area sample.

The decision rules, with α set at 0.10, are

If $T > w_{0.10}$, conclude failure to meet the performance standard
If $T \leq w_{0.10}$, conclude that the performance standard was met

where $w_{0.10}$ is the critical value of T observed in Appendix Table A-4 given n_1 and n_2 (the number of observations in the reclamation sample).

An example of the use of the Mann-Whitney test follows. Let's assume we have collected 20 shrub-density observations from both a reference area and a reclaimed area, as indicated below

Reference Area Observation	log (Observation+1) + log (0.9)	Rank	Reference Area Observation	log (Observation+1) + log (0.9)	Rank
			0	0	1.5
			0	0	1.5
3	0.5563	3			
10	0.9956	4			
17	1.2095	5			
22	1.3160	6.5			
22	1.3160	6.5			
23	1.3345	8			
27	1.4014	9			
			25	1.4150	10
			29	1.4771	11
33	1.4857	12			
35	1.5105	13.5			
35	1.5105	13.5			
36	1.5224	15			
37	1.5340	16.5			
37	1.5340	16.5			
			35	1.5563	18.5
			35	1.5563	18.5
			38	1.5911	20
			40	1.6128	21
45	1.6170	23			
45	1.6170	23			
45	1.6170	23			
			42	1.6335	25
			44	1.6532	26.5
49	1.6532	26.5			
			45	1.6628	28
			48	1.6902	29
55	1.7024	30			
			50	1.7076	31
			51	1.7160	32
			58	1.7709	33
			60	1.7853	34

			65	1.8195	35
			75	1.8808	36
			78	1.8976	37
			132	2.1239	38
192	2.2398	39			
415	2.5733	40			

Therefore 333.5 = $S_{reference}$, and

$$T = (333.5) - \frac{20\,(20 + 1)}{2} = 123.5$$

Since the calculated T value is less than the critical value of 152 ($w_{0.10}$ with $n_1 = 20$, $n_2 = 20$) from Appendix Table A-4, we conclude that the performance standard was met.

Daniel (1990) presents a large-sample normal approximation when either n_1 or n_2 are more than 20

$$z = \frac{T - n_1 n_2 / 2}{\sqrt{n_1 n_2 (n_1 + n_2 + 1) / 12}}$$

Inserting the calculated T value and sample sizes from the shrub-density example, we have

$$z = \frac{123.5 - (20 \times 20/2)}{\sqrt{20 \times 20\,(20 + 20 + 1) / 12}} = -2.07$$

Appendix Table A-3 indicates that the probability of observing a value of z this small is 0.0192, and as above, we conclude that the performance standard was met.

Woody-taxa density is a difficult vegetation attribute to estimate, but the Mann-Whitney test appears to be a very promising technique. Therefore another example is provided, using actual reference area and baseline shrub-density observations from an upland grassland physiognomic type (the baseline data, for the purpose of this example, are considered to be from reclamation). If the summary statistics for the following data are used to estimate the sample size for a comparison of means, the ratio d/s = 0.24, and the estimated minimum sample size is well over 100 observations from each population. This seems excessive. Both populations are positively skewed and there are a large number of zero values, which seems reasonable for shrub densities in a composite of upland grassland communities. The Mann-Whitney test is indicated.

Reference Area			Reclamation		
Observation	log (Observation + 1) + log (0.9)	Rank	Observation	log (Observation + 1)	Rank
0	−0.046	5			
0	−0.046	5			
0	−0.046	5			
0	−0.046	5			
0	−0.046	5			
0	−0.046	5			
0	−0.046	5			
0	−0.046	5			
0	−0.046	5			
			0	0	14.5
			0	0	14.5
			0	0	14.5
			0	0	14.5
			0	0	14.5
			0	0	14.5
			0	0	14.5
			0	0	14.5
			0	0	14.5
			0	0	14.5
167	2.180	20			
			167	2.225	21.5
			167	2.225	21.5
333	2.478	23			
334	2.479	24.5			
334	2.479	24.5			
			333	2.524	26.5
			333	2.524	26.5
			334	2.525	29.5
			334	2.525	29.5
500	2.654	31.5			
500	2.654	31.5			
			500	2.700	33.5
			500	2.700	33.5
666	2.778	35.5			
666	2.778	35.5			
667	2.779	37			
			667	2.825	38
833	2.875	39			
			834	2.922	40
1000	2.955	41.5			
1000	2.955	41.5			
1167	3.022	43			
1333	3.079	44			
1334	3.080	45.5			
1334	3.080	45.5			
1499	3.130	47			
1500	3.131	48.5			
1500	3.131	48.5			
			1667	3.222	50
2000	3.255	51			
			2000	3.301	52
			2334	3.368	53
			3167	3.501	54
			3334	3.523	55

Reference Area Observation	log (Observation + 1) + log (0.9)	Rank	Reclamation Observation	log (Observation + 1)	Rank
3833	3.538	56			
			3667	3.564	57
			4000	3.602	58.5
			4000	3.602	58.5
			4333	3.637	60
			4500	3.653	61
			5000	3.699	62
7334	3.820	63.5			
7334	3.820	63.5			
8500	3.884	65			
			8834	3.946	66
			10500	4.021	67
			20166	4.305	68

Therefore, $S_{reference} = 1051$

$$T = (1051) - \frac{34\,(34+1)}{2} = 456, \quad \text{and} \quad z = \frac{456 - (34 \times 34 / 2)}{\sqrt{34 \times 34\,(34 + 34 + 1) / 12}} = -1.50$$

From Appendix Table A-3, the probability of randomly observing a *z* value of -1.50 is 0.0668, and we conclude that the performance standard was met.

Note that in the second example above, all of the tied observation ranks occurred within either one population or the other, so averaging the ranks wasn't really necessary, except to demonstrate the procedure.

Reference:

Daniel, W.W. 1990. Applied Nonparametric Statistics, 2nd ed. PWS-KENT PublishingCo., Boston, MA. 635 pp.

7. The Satterthwaite correction:

The presence of unequal sample variances in two populations which are going to be compared results in a *t* statistic which does not follow Student's *t* distribution. The Satterthwaite correction assigns an appropriate number of degrees of freedom to the calculated *t* so that the ordinary *t* table (Appendix Table A-1) may be used. The corrected degrees of freedom are given by

$$v' = \frac{\left(\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}\right)^2}{\frac{\left(\frac{s_1^2}{n_1}\right)^2}{n_1 - 1} + \frac{\left(\frac{s_2^2}{n_2}\right)^2}{n_2 - 1}}$$

where s_1^2 and s_2^2 are the sample variances for the 2 populations , and n_1 and n_2 are the respective sample sizes. An example from Snedecor and Cochran (1980) follows. Four observations from one population are going to be compared to 8 observations from a second population. The summary statistics are

$n_1 = 4$, with 3 degrees of freedom	$n_2 = 8$, with 7 degrees of freedom
$\bar{x}_1 = 25$	$\bar{x}_2 = 21$
$s_1^2 = 0.67$	$s_2^2 = 17.71$
$s_1^2/n_1 = 0.17$	$s_2^2/n_2 = 2.21$

Without taking the Satterthwaite correction into account, the degrees of freedom for the *t* statistic would be calculated as $n_1 + n_2 - 2 = 10$. Correcting for unequal variances yields

$$v' = \frac{\left(\frac{0.67}{4} + \frac{17.71}{8}\right)^2}{\frac{\left(\frac{0.67}{4}\right)^2}{4-1} + \frac{\left(\frac{17.71}{8}\right)^2}{8-1}} = 7.99$$

Therefore, the *t* value from Appendix Table A-1 which is associated with 8 degrees of freedom (1.397 for a one-sided test) is the proper comparative statistic to use when designating the decision rules.

Reference:

Snedecor, G.W., and Cochran, W.G. 1980. Statistical Methods, 7th ed. Iowa State University Press. 507 pp.

8. Data transformation:

Data transformations are applied to change the scale of measurements in order to better approximate the normal distribution. However, if the Department's recommendations are followed to (1) take a minimum of 30 observations from each population of interest to invoke the central limit theorem, and (2) always take the same number of observations from each population being compared to decrease sensitivity to heterogeneous variances, the need for data transformation should be minimized.

Three basic rules applicable to the use of all transformations are given by Krebs (1989):

1. Never convert *variances, standard deviations,* or *standard errors* back to the original measurement scale. These statistics have no meaning on the original scale of measurement.

2. *Means* and *confidence limits* may be converted back to the original scale by applying the inverse transformation.

3. Never compare means calculated from untransformed data with means calculated from any transformation, reconverted back to the original scale of measurement. They are not comparable means. All statistical comparisons between different groups must be done using one common transformation for all groups.

The **arcsine transformation** is used to approximate the normal distribution for percentages (such as percent cover) and proportions which naturally form binomial distributions when there are two possible outcomes, or multinomial distributions when there are three or more potential outcomes. As previously mentioned, if percentages range from about 30 to 70%, as is typical with Montana vegetation cover data, there is no need for transformation. If many values are nearer to 0 or 100%, however, the arcsine transformation should be used. Note that arcsine = $\sin^{-1}$. The observation from the original data is replaced by the transformed observation (X^1). The arcsine transformation recommended by Krebs (1989) is

$$X' = \text{arcsine}\sqrt{p}$$

where p is the observed proportion.

To convert arcsine-transformed means back to the original scale of percentages or proportions the procedure is reversed.

$$\overline{p} = (\sin \overline{X'})^2$$

The **square-root transformation** is commonly applied when sample variances are proportional to the sample means.

$$X' = \sqrt{X + 0.5}$$

This transformation is preferable to the straight square-root transformation when the original data include small numbers and some zero values. The mean may be converted back to the original scale by reversing the transformation.

$$\overline{X} = (\overline{X'})^2 - 0.5$$

The **logarithmic transformation** is used when percent changes or multiplicative effects (such as multiplying observations by a 90% performance standard, as previously discussed) occur. This transformation will convert a positively-skewed frequency distribution into a more nearly symmetrical distribution.

$$X' = \log (X + 1)$$

Either natural (base *e*) or base 10 logs may be used. Conversion of the mean back to the original scale is accomplished by

$$\overline{X} = [\operatorname{antilog}(\overline{X'})] - 1 = 10^{\overline{X'}} - 1$$

Reference:

Krebs, C. J. 1989. Ecological Methodology. Harper and Row, New York, NY. 654 pp.

Table A-1: Percentiles of the *t* distribution for $\alpha = 0.10$ (one-tailed and two-tailed)

Degrees of freedom (n – 1)	One-tailed *t* value	Two-tailed *t* value
1	3.078	6.314
2	1.886	2.920
3	1.638	2.353
4	1.533	2.132
5	1.476	2.015
6	1.440	1.943
7	1.415	1.895
8	1.397	1.860
9	1.383	1.833
10	1.372	1.812
11	1.363	1.796
12	1.356	1.782
13	1.350	1.771
14	1.345	1.761
15	1.341	1.753
16	1.337	1.746
17	1.333	1.740
18	1.330	1.734
19	1.328	1.729
20	1.325	1.725
21	1.323	1.721
22	1.321	1.717
23	1.319	1.714
24	1.318	1.711
25	1.316	1.708
26	1.315	1.706
27	1.314	1.703
28	1.313	1.701
29	1.311	1.699
30	1.310	1.697
40	1.303	1.684
60	1.296	1.671
120	1.289	1.658
∞	1.282	1.645

Adapted from Neter, J., Wasserman, W., and Kutner, M. H. 1985. Applied Linear Statistical Models, 2nd ed.

Table A-2: The binomial probability distribution for a population expected to yield minus signs 50% of the time when H_o is true

The tabulated probabilities are additive. For example, if we want to determine the probability that $K \leq 4$ when n = 11, we add the probabilities for each r value from 0 to 4 in the n = 11 column to obtain the sum of 0.2745.

n =	1	2	3	4	5	6	7	8	9	10	11
r = 0	.5000	.2500	.1250	.0625	.0312	.0156	.0078	.0039	.0020	.0010	.0005
1	.5000	.5000	.3750	.2500	.1562	.0938	.0547	.0312	.0176	.0098	.0054
2		.2500	.3750	.3750	.3125	.2344	.1641	.1094	.0703	.0439	.0269
3			.1250	.2500	.3125	.3125	.2734	.2188	.1641	.1172	.0806
4				.0625	.1562	.2344	.2734	.2734	.2461	.2051	.1611
5					.0312	.0938	.1641	.2188	.2461	.2461	.2256
6						.0156	.0547	.1094	.1641	.2051	.2256
7							.0078	.0312	.0703	.1172	.1611
8								.0039	.0176	.0439	.0806
9									.0020	.0098	.0269
10										.0010	.0054
11											.0005

Table A-2 continues on page A19

Table A-2: The binomial probability distribution--continued

n =	12	13	14	15	16	17	18	19	20	25
r = 0	.0002	.0001	.0001	.0000	.0000	.0000	.0000	.0000	.0000	.0000
1	.0029	.0016	.0009	.0005	.0002	.0001	.0001	.0000	.0000	.0000
2	.0161	.0095	.0056	.0032	.0018	.0010	.0006	.0003	.0002	.0000
3	.0537	.0349	.0222	.0139	.0085	.0052	.0031	.0018	.0011	.0001
4	.1208	.0873	.0611	.0417	.0278	.0182	.0117	.0074	.0046	.0004
5	.1934	.1571	.1222	.0916	.0667	.0472	.0327	.0222	.0148	.0016
6	.2256	.2095	.1833	.1527	.1222	.0944	.0708	.0518	.0370	.0053
7	.1934	.2095	.2095	.1964	.1746	.1484	.1214	.0961	.0739	.0143
8	.1208	.1571	.1833	.1964	.1964	.1855	.1669	.1442	.1201	.0322
9	.0537	.0873	.1222	.1527	.1746	.1855	.1855	.1762	.1602	.0609
10	.0161	.0349	.0611	.0916	.1222	.1484	.1669	.1442	.1762	.0974
11	.0029	.0095	.0222	.0417	.0667	.0944	.1214	.0961	.1602	.1328
12	.0002	.0016	.0056	.0139	.0278	.0472	.0708	.0518	.1201	.1550
13		.0001	.0009	.0032	.0085	.0182	.0327	.0222	.0739	.1550
14			.0001	.0005	.0018	.0052	.0117	.0074	.0370	.1328
15					.0002	.0010	.0031	.0018	.0148	.0974
16						.0001	.0006	.0003	.0046	.0609
17							.0001		.0011	.0322
18									.0002	.0143
19										.0053
20										.0016
21										.0004
22										.0001

Adapted from Daniel, W.W. 1990. Applied Nonparametric Statistics, 2nd ed.

Table A-3: Standard one-tailed normal curve areas

Table entries give the area under the normal curve from 0 to *z.* Subtract the table entry from 0.5 to obtain the tail area of the curve, which is the probability of randomly observing a value of *z* which is equal to, or more extreme than, the calculated *z* value. If calculated values have negative signs, disregard the sign when using this table. For example, the table entry for $z = -1.96$ is 0.4750, and the probability of randomly observing that *z* value is 0.0250.

z	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
0.0	.0000	.0040	.0080	.0120	.0160	.0199	.0239	.0279	.0319	.0359
0.1	.0398	.0438	.0478	.0517	.0557	.0596	.0636	.0675	.0714	.0753
0.2	.0793	.0832	.0871	.0910	.0948	.0987	.1026	.1064	.1103	.1141
0.3	.1179	.1217	.1255	.1293	.1331	.1368	.1406	.1443	.1480	.1517
0.4	.1554	.1591	.1628	.1664	.1700	.1736	.1772	.1808	.1844	.1879
0.5	.1915	.1950	.1985	.2019	.2054	.2088	.2133	.2157	.2190	.2224
0.6	.2257	.2291	.2324	.2357	.2389	.2422	.2454	.2486	.2517	.2549
0.7	.2580	.2611	.2642	.2673	.2704	.2734	.2764	.2794	.2823	.2852
0.8	.2881	.2910	.2939	.2967	.2995	.3023	.3051	.3078	.3106	.3133
0.9	.3159	.3186	.3212	.3238	.3264	.3289	.3315	.3340	.3365	.3389
1.0	.3413	.3438	.3461	.3485	.3508	.3531	.3554	.3577	.3599	.3621
1.1	.3643	.3665	.3686	.3708	.3729	.3749	.3770	.3790	.3810	.3830
1.2	.3849	.3869	.3888	.3907	.3925	.3944	.3962	.3980	.3997	.4015
1.3	.4032	.4049	.4066	.4082	.4099	.4115	.4131	.4147	.4162	.4177
1.4	.4192	.4207	.4222	.4236	.4251	.4265	.4279	.4292	.4306	.4319
1.5	.4332	.4345	.4357	.4370	.4382	.4394	.4406	.4418	.4429	.4441
1.6	.4452	.4463	.4474	.4484	.4495	.4505	.4515	.4525	.4535	.4545
1.7	.4554	.4564	.4573	.4582	.4591	.4599	.4608	.4616	.4625	.4633
1.8	.4641	.4649	.4656	.4664	.4671	.4678	.4686	.4693	.4699	.4706
1.9	.4713	.4719	.4726	.4732	.4738	.4744	.4750	.4756	.4761	.4767
2.0	.4772	.4778	.4783	.4788	.4793	.4798	.4803	.4808	.4812	.4817
2.1	.4821	.4826	.4830	.4834	.4838	.4842	.4846	.4850	.4854	.4857
2.2	.4861	.4864	.4868	.4871	.4875	.4878	.4881	.4884	.4887	.4890
2.3	.4893	.4896	.4898	.4901	.4904	.4906	.4909	.4911	.4913	.4916
2.4	.4918	.4920	.4922	.4925	.4927	.4929	.4931	.4932	.4934	.4936
2.5	.4938	.4940	.4941	.4943	.4945	.4946	.4948	.4949	.4951	.4952
2.6	.4953	.4955	.4956	.4957	.4959	.4960	.4961	.4962	.4963	.4964
2.7	.4965	.4966	.4967	.4968	.4969	.4970	.4971	.4972	.4973	.4974
2.8	.4974	.4975	.4976	.4977	.4977	.4978	.4979	.4979	.4980	.4981
2.9	.4981	.4982	.4982	.4983	.4984	.4984	.4985	.4985	.4986	.4986
3.0	.4987	.4987	.4987	.4988	.4988	.4989	.4989	.4989	.4990	.4990

Adapted from Snedecor, G.W., and Cochran, W.G. 1980. Statistical Methods, 7th ed.

Table A-4: Values of $w_{0.10}$ for the Mann-Whitney test statistic

n_1	$n_2=$	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
2		0	1	1	2	2	2	3	3	4	4	5	5	5	6	6	7	7	8	8
3		1	2	2	3	4	5	6	6	7	8	9	10	11	11	12	13	14	15	16
4		1	2	4	5	6	7	8	10	11	12	13	14	16	17	18	19	21	22	23
5		2	3	5	6	8	9	11	13	14	16	18	19	21	23	24	26	28	29	31
6		2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	35	37	39
7		2	5	7	9	12	14	17	19	22	24	27	29	32	34	37	39	42	44	47
8		3	6	8	11	14	17	20	23	25	28	31	34	37	40	43	46	49	52	55
9		3	6	10	13	16	19	23	26	29	32	36	39	42	46	49	53	56	59	63
10		4	7	11	14	18	22	25	29	33	37	40	44	48	52	55	59	63	67	71
11		4	8	12	16	20	24	28	32	37	41	45	49	53	58	62	66	70	74	79
12		5	9	13	18	22	27	31	36	40	45	50	54	59	64	68	73	78	82	87
13		5	10	14	19	24	29	34	39	44	49	54	59	64	69	75	80	85	90	95
14		5	11	16	21	26	32	37	42	48	53	59	64	70	75	81	86	92	98	103
15		6	11	17	23	28	34	40	46	52	58	64	69	75	81	87	93	99	105	111
16		6	12	18	24	30	37	43	49	55	62	68	75	81	87	94	100	107	113	120
17		7	13	19	26	32	39	46	53	59	66	73	80	86	93	100	107	114	121	128
18		7	14	21	28	35	42	49	56	63	70	78	85	92	99	107	114	121	129	136
19		8	15	22	29	37	44	52	59	67	74	82	90	98	105	113	121	129	136	144
20		8	16	23	31	39	47	55	63	71	79	87	95	103	111	120	128	136	144	152

Adapted from Daniel, W.W. 1990. Applied Nonparametric Statistics, 2nd ed.

APPENDIX B

Vegetation and Land Use Rules

Table B-1. A listing of administrative rules addressing vegetation and land use requirements.

ARM	Subject
Definitions	
17.24.301(6)	Adjacent area
17.24.301(8)	Agricultural activities or farming
17.24.301(9)	Agricultural use
17.24.301(10)	Alluvial valley floor
17.24.301(11)	Alternative post-mining land use
17.24.301(16)	Arid and semiarid area
17.24.301(19)	Best technology currently available
17.24.301(28)	Cover
17.24.301(32)	Disturbed area
17.24.301(39)	Essential hydrologic functions
17.24.301(41)	Farm
17.24.301(43)	Flood irrigation
17.24.301(44)	Fragile lands
17.24.301(46)	Good ecological integrity
17.24.301(50)	Higher or better use
17.24.301(53)	Historically used for cropland
17.24.301(62)	Irreparable damage to the environment
17.24.301(64)	Land use
17.24.301(65)	Major Revision
17.24.301(72)	Mulch
17.24.301(75)	Noxious plants
17.24.301(90)	Prime farmland
17.24.301(93)	Productivity
17.24.301(99)	Rangeland
17.24.301(101)	Reclamation
17.24.301(103)	Reference area
17.24.301(105)	Renewable resource lands
17.24.301(107)	Road
17.24.301(109)	Sediment

Table B-1. - continued

ARM	Subject
17.24.301(111)	Significant, imminent environmental harm
17.24.301(112)	Soil
17.24.301(115)	Spoil
17.24.301(116)	Stabilize
17.24.301(117)	Subirrigation
17.24.301(120)	Substantially disturb
17.24.301(133)	Undeveloped rangeland
17.24.301(135)	Upland area
Application Requirements	
17.24.302	Format and supplemental information
17.24.304	Baseline information
17.24.305	Maps
17.24.306	Prime farmland investigation
17.24.308(f)	Noxious weed control plan
17.24.312	Fish and wildlife plan (T&E spp.)
17.24.313	Reclamation plan
17.24.314	Protection of hydrologic balance
17.24.324	Prime farmlands: special application requirements
17.24.325	Alluvial valley floors: special application requirements
Permit Procedures	
17.24.404	Adequacy of fish and wildlife plan
17.24.415	Permit revisions
17.24.416	Permit renewal
17.24.417	Permit amendment
Backfilling and Grading Requirements	
17.24.503	Small depressions
17.24.504	Permanent impoundments
17.24.515	Highwall reduction
17.24.518	Buffer zones
17.24.520	Disposal of excess spoil

Table B-1. - continued

ARM	Subject
Transportation Facilities	
17.24.601	General requirements for roads and railroad loop construction
17.24.602	Location of roads and railroad loops
17.24.605	Hydrologic impact of roads and railroad loops
17.24.608	Impacts of other transport facilities
17.24.609	Other support facilities
17.24.610	Permanent roads
Hydrology	
17.24.631	General hydrology requirements
17.24.633	Water quality performance standards
17.24.634	Reclamation of drainage basins
17.24.636	Special requirements for temporary diversions
17.24.638	Sediment control measures
17.24.644	Protection of groundwater recharge
17.24.650	Post-mining rehabilitation of sediment ponds
17.24.651	Stream channel disturbances and buffer zones
Revegetation and Protection of Wildlife	
17.24.702	Redistribution and stockpiling of soil
17.24.703	Substitution of other materials for soil
17.24.711	Establishment of vegetation
17.24.713	Timing of seeding and planting
17.24.714	Soil stabilizing practices
17.24.716	Method of revegetation
17.24.717	Planting of trees and shrubs
17.24.718	Soil amendments, management techniques, and land use practices
17.24.721	Eradication of rills and gullies
17.24.723	Monitoring
17.24.724	Use of revegetation comparison standards
17.24.725	Period of responsibility
17.24.726	Vegetation production, cover, diversity, density, and utility requirements
17.24.731	Analysis for toxicity
17.24.751	Protection and enhancement of fish and wildlife
17.24.761	Air resources protection
17.24.762	Post-mining land use

Table B-1. - continued

ARM	Subject
Alluvial Valley Floors	
17.24.801	Preservation of hydrologic functions and protection of farming
17.24.802	Protection of farming and prevention of material damage
17.24.804	Monitoring
17.24.805	Significance determination
17.24.806	Material damage determination
Prime Farmlands	
17.24.811	Soil handling
17.24.815	Revegetation
Alternate Post-mining Land Use	
17.24.821	Submission of plan
17.24.823	Approval of plan and review of operation
Prospecting	
17.24.1008	Revegetation
Bonding	
17.24.1116	Criteria and schedule for release of bond
Designation of Lands Unsuitable	
17.24.1141	Definition

APPENDIX C

Montana Range Plants

by

Carl Wambolt*

Purpose

Regardless of backgrounds, people working with range plants are often perplexed at the lack of consistency among the many reference materials available on nomenclature and other pertinent plant characteristics. Thus the purpose of this painstaking compilation is an attempt to cite the currently most acceptable nomenclature and information relating to plant longevity, origin, season of growth and grazing response to cattle.

Undoubtedly many readers will find points of disagreement with their current understandings. However, if we expect to communicate effectively with one another, then standardization such as offered in this work will be necessary. Certainly, some points are subject to change as our knowledge increases through research and experience. Also, it is possible that errors do exist in this work and if discovered the author would appreciate learning of them so that corrections can be made in subsequent printings.

A great many thank-yous are in order for those individuals who spent hours reviewing the materials. While it is probably unwise to name individuals for fear of neglecting some, the range staff of the Soil Conservation Service, USDA, located in Montana, and the Range Science staff at Montana State University deserve special mention.

How To Use This Publication

Each plant is listed twice, once alphabetically by scientific name, and again alphabetically by common name. The reader should choose the listing he finds easiest to use.

Plants are subdivided by vegetative class, including: 1) grass; 2) grasslike plants; 3) forbs, ferns and mosses; 4) cactus; and, 5) half-shrubs, shrubs, trees and vines.

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The four capital letters following each plant name provide the following information:

I. **First column** — *Longevity*
- P = perennial
- B = biennial
- A = annual

II. **Second column** — *Origin*
- N = native (to North America)
- I = introduced (to North America)

III. **Third column** — *Season of Growth*
- C = cool season (flowers during spring or early summer)
- W = warm season (flowers during late summer or fall)
- X = inappropriate

IV. **Fourth column** — *Grazing Response to Cattle Use**
- D = decreaser
- I = increaser
- V = invader
- X = inappropriate

*It is important to realize that grazing responses of individual plants often change greatly with use by different classes of animals.

Grasses (Common Name)

Common Name	Longevity	Origin	Season	Gr. Response	
Alkali bluegrass	P	N	C	D	*Poa juncifolia*
Alkali cordgrass	P	N	W	D	*Spartina gracilis*
Alkali muhly	P	N	W	I	*Muhlenbergia asperifolia*
Alkali sacaton	P	N	W	D	*Sporobolus airoides*
Alpine bluegrass	P	N	C	D	*Poa alpina*
Alpine foxtail	P	N	C	D	*Alopecurus alpinus*
Alpine timothy	P	N	C	D	*Phleum alpinum*
American mannagrass	P	N	C	D	*Glyceria grandis*
American sloughgrass	A	N	C	V	*Beckmannia syzigachne*
Annual bluegrass	A	I	C	V	*Poa annua*
Barnyardgrass	A	I	W	V	*Echinochloa crusgalli*
Basin wildrye	P	N	C	D	*Elymus cinereus*
Bearded wheatgrass	P	N	C	D	*Agropyron subsecundum*
Beardless wheatgrass	P	N	C	D	*Agropyron spicatum var. inerme*
Big bluegrass	P	N	C	D	*Poa ampla*
Big bluestem	P	N	W	D	*Andropogon gerardii*
Bluebunch wheatgrass	P	N	C	D	*Agropyron spicatum*
Blue grama	P	N	W	I	*Bouteloua gracilis*
Bluejoint reedgrass	P	N	C	D	*Calamagrostis canadensis*
Blue wildrye	P	N	C	D	*Elymus glaucus*
Bottlebrush squirreltail	P	N	C	I	*Sitanion hystrix*
Brookgrass	P	N	C	D	*Catabrosa aquatica*
Buffalograss	P	N	W	I	*Buchloe dactyloides*
Bulbous bluegrass	P	I	C	V	*Poa bulbosa*
California brome	A	N	C	V	*Bromus carinatus*
California danthonia	P	N	C	I	*Danthonia californica*
Canada bluegrass	P	I	C	V	*Poa compressa*
Canada wildrye	P	N	C	D	*Elymus canadensis*
Canarygrass	A	I	C	V	*Phalaris canariensis*
Canby bluegrass	P	N	C	D	*Poa canbyi*
Cheatgrass	A	I	C	V	*Bromus tectorum*
Chess brome	A	I	C	V	*Bromus secalinus*
Columbia needlegrass	P	N	C	D	*Stipa columbiana*
Common reedgrass	P	N	W	D	*Phragmites communis*
Crested wheatgrass	P	I	C	V	*Agropyron cristatum*
Cusick bluegrass	P	N	C	I	*Poa cusickii*
Drooping woodreed	P	N	C	I	*Cinna latifolia*
False buffalograss	A	N	W	V	*Munroa squarrosa*
Fendler threeawn	P	N	W	I	*Aristida fendleriana*
Fowl bluegrass	P	I	C	V	*Poa palustris*
Foxtail barley	P	N	C	I	*Hordeum jubatum*
Fringed brome	P	N	C	D	*Bromus ciliatus*
Green bristlegrass	A	I	W	V	*Setaria viridis*
Green needlegrass	P	N	C	D	*Stipa viridula*
Hairy brome	A	I	C	V	*Bromus commutatus*
Hard sheep fescue	P	I	C	V	*Festuca ovina var. duriuscula*
Idaho fescue	P	N	C	I*	*Festuca idahoensis*
Idaho redtop	P	N	C	D	*Agrostis idahoensis*

Indian ricegrass	P N C D	*Oryzopsis hymenoides*
Inland saltgrass	P N W I	*Distichlis stricta*
Intermediate wheatgrass	P I C V	*Agropyron intermedium*
Italian ryegrass	P I C V	*Lolium multiflorum*
Japanese brome	A I C V	*Bromus japonicus*
Jointed goatgrass	A I C V	*Aegilops cylindrica*
Kentucky bluegrass	P I C V	*Poa pratensis*
Letterman needlegrass	P N C D	*Stipa lettermani*
Little bluestem	P N W D	*Schizachyrium scoparium*
Little barley	A N C V	*Hordeum pusillum*
Macoun wildrye	P N C D	*Elymus macounii*
Marsh muhly	P N W I	*Muhlenbergia racemosa*
Mat muhly	P N W I	*Muhlenbergia richardsonis*
Meadow barley	P N C I	*Hordeum brachyantherum*
Meadow fescue	P I C V	*Festuca elatior* (*F. pratensis*)
Meadow foxtail	P I C V	*Alopecurus pratensis*
Mountain brome	P N C D	*Bromus marginatus* (*B. carinatus*)
Mountain hairgrass	P N C D	*Deschampsia atropurpurea*
Mountain muhly	P N W D	*Muhlenbergia montana*
Muttongrass	P N C D	*Poa fendleriana*
Needleandthread	P N C I	*Stipa comata*
Nevada bluegrass	P N C I	*Poa nevadensis*
Nodding brome	P N C D	*Bromus anomalus*
Nuttall alkaligrass	P N C D	*Puccinellia nuttalliana* (*P. airoides*)
Onespike danthonia	P N C I	*Danthonia unispicata*
Oniongrass	P N C D	*Melica bulbosa*
Orchardgrass	P I C V	*Dactylis glomerata*
Parry danthonia	P N C I	*Danthonia parryi*
Perennial ryegrass	P I C V	*Lolium perenne*
Persian ryegrass	A I C V	*Lolium persicum*
Pine bluegrass	P N C I	*Poa scabrella*
Pinegrass	P N C I	*Calamagrostis rubescens*
Plains bluegrass	P N C I	*Poa arida*
Plains muhly	P N W D	*Muhlenbergia cuspidata*
Plains reedgrass	P N C I	*Calamagrostis montanensis*
Porcupinegrass	P N C D	*Stipa spartea*
Poverty danthonia	P N C I	*Danthonia spicata*
Prairie cordgrass	P N W D	*Spartina pectinata*
Prairie junegrass	P N C I	*Koeleria cristata*
Prairie sandreed	P N W D	*Calamovilfa longifolia*
Pubescent wheatgrass	P I C V	*Agropyron trichophorum*
Purple oniongrass	P N C D	*Melica spectabilis*
Purple reedgrass	P N C D	*Calamagrostis purpurascens*
Quackgrass	P I C V	*Agropyron repens*
Rabbitfootgrass	A I C V	*Polypogon monspeliensis*
Rattlesnake brome	A I C V	*Bromus brizaeformis*
Red fescue	P I C V	*Festuca rubra*
Red threeawn	P N W I	*Aristida longiseta*
Redtop	P I C V	*Agrostis alba*
Reed canarygrass	P N C D	*Phalaris arundinacea*
Richardson needlegrass	P N C D	*Stipa richardsonii*
Rough fescue	P N C D	*Festuca scabrella*
Russian wildrye	P I C V	*Elymus junceus*
Sandberg bluegrass	P N C I	*Poa sandbergii*
Sand bluestem	P N W D	*Andropogon hallii*
Sandbur	A N W V	*Cenchrus longispinus*
Sand dropseed	P N W I	*Sporobolus cryptandrus*
Scribner wheatgrass	P N C D	*Agropyron scribneri*
Sheep fescue	P N C I	*Festuca ovina*
Shortawn foxtail	P N C D	*Alopecurus aequalis*
Sideoats grama	P N W D	*Bouteloua curtipendula*
Sixweeks fescue	A N C V	*Vulpia octoflora*
Slender wheatgrass	P N C D	*Agropyron trachycaulum* (*A. caninum*)
Smooth brome	P I C V	*Bromus inermis*
Soft brome	A I C V	*Bromus mollis*
Spike bentgrass	P N C D	*Agrostis exarata*
Spikefescue	P N C D	*Hesperochloa kingii*
Spikeoat	P N C I	*Helictotrichon hookeri*
Spiketrisetum	P N C D	*Trisetum spicatum*
Stinkgrass	A I W V	*Eragrostis cilianensis*
Streambank wheatgrass	P N C I	*Agropyron riparium*
Sweetgrass	P N C D	*Hierochloe odorata*
Switchgrass	P N W D	*Panicum virgatum*
Thickspike wheatgrass	P N C I*	*Agropyron dasystachyum*
Ticklegrass	P N C I	*Agrostis scabra*
Timber danthonia	P N C I	*Danthonia intermedia*
Timothy	P I C V	*Phleum pratense*
Tufted hairgrass	P N C D	*Deschampsia caespitosa*
Tumblegrass	P N W I	*Schedonnardus paniculatus*
Velvetgrass	P I C V	*Holcus lanatus*
Weeping alkaligrass	P I C V	*Puccinellia distans*
Western needlegrass	P N C D	*Stipa occidentalis*
Western wheatgrass	P N C I*	*Agropyron smithii*
Wild oat	A I C V	*Avena fatua*
Williams needlegrass	P N C D	*Stipa williamsii*
Witchgrass	A N W V	*Panicum capillare*
Yellow bristlegrass	A I W V	*Setaria lutescens*

Grasses (Scientific Name)

	Longevity	Origin	Season	Gr. Response	
Aegilops cylindrica	A	I	C	V	jointed goatgrass
Agropyron cristatum[1]	P	I	C	I	crested wheatgrass
A. dasystachyum[2]	P	N	C	I*	thickspike wheatgrass
A. intermedium	P	I	C	V	intermediate wheatgrass
A. repens	P	I	C	V	quackgrass
A. riparium	P	N	C	I	streambank wheatgrass
A. scribneri	P	N	C	D	Scribner wheatgrass
A. smithii	P	N	C	I*	western wheatgrass
A. spicatum	P	N	C	D	bluebunch wheatgrass
A. spicatum var. inerme	P	N	C	D	beardless wheatgrass
A. subsecundum	P-N		C	D	bearded wheatgrass

[1] *Agropyron cristatum* complex includes: *A. desertorum*, *A. pectiniforme* and *A. sibiricum*.

[2] *Agropyron dasystachyum* complex includes: *A. albicans*, *A.* [illegible] and *A. griffithsii*.

*Commonly encountered as a decreaser, but more often reacts as an increaser.

A. trachycaulum (A. caninum)	P N C D	slender wheatgrass
A. trichophorum	P I C V	pubescent wheatgrass
Agrostis alba	P I C V	redtop
A. exarata	P N C D	spike bentgrass
A. idahoensis	P N C D	Idaho redtop
A. scabra	P N C I	ticklegrass
Alopecurus aequalis	P N C D	shortawn foxtail
A. alpinus	P N C D	alpine foxtail
A. pratensis	P I C V	meadow foxtail
Andropogon gerardii	P N W D	big bluestem
A. hallii	P N W D	sand bluestem
Aristida fendleriana	P N W I	Fendler threeawn
A. longiseta	P N W I	red threeawn
Avena fatua	A I C V	wild oat
Beckmannia syzigachne	A N C V	American sloughgrass
Bouteloua curtipendula	P N W D	sideoats grama
B. gracilis	P N W I	blue grama
Bromus anomalus	P N C D	nodding brome
B. brizaeformis	A I C V	rattlesnake brome
B. carinatus	A N C V	California brome
B. ciliatus	P N C D	fringed brome
B. commutatus	A I C V	hairy brome
B. inermis	P I C V	smooth brome
B. japonicus	A I C V	Japanese brome
B. marginatus (B. carinatus)	P N C D	mountain brome
B. mollis	A I C V	soft brome
B. secalinus	A I C V	chess brome
B. tectorum	A I C V	cheatgrass
Buchloe dactyloides	P N W I	buffalograss
Calamagrostis canadensis	P N C D	bluejoint reedgrass
C. montanensis	P N C I	plains reedgrass
C. purpurascens	P N C D	purple reedgrass
C. rubescens	P N C I	pinegrass
Calamovilfa longifolia	P N W D	prairie sandreed
Catabrosa aquatica	P N C D	brookgrass
Cenchrus longispinus	A N W V	sandbur
Cinna latifolia	P N C I	drooping woodreed
Dactylis glomerata	P I C V	orchardgrass
Danthonia californica	P N C I	California danthonia
D. intermedia	P N C I	timber danthonia
D. parryi	P N C I	Parry danthonia
D. spicata	P N C I	poverty danthonia
D. unispicata	P N C I	onespike danthonia
Deschampsia atropurpurea	P N C D	mountain hairgrass
D. caespitosa	P N C D	tufted hairgrass
Distichlis stricta	P N W I	inland saltgrass
Echinochloa crusgalli	A I W V	barnyardgrass
Elymus canadensis	P N C D	Canada wildrye
E. cinereus	P N C D	basin wildrye
E. glaucus	P N C D	blue wildrye
E. junceus	P I C V	Russian wildrye
E. macounii	P N C D	Macoun wildrye
Eragrostis cilianensis	A I W V	stinkgrass
Festuca elatior (F. pratensis)	P I C V	meadow fescue
F. idahoensis	P N C I*	Idaho fescue
F. ovina	P N C I	sheep fescue
F. ovina var. duriuscula	P I C V	hard sheep fescue
F. rubra	P I C V	red fescue
F. scabrella	P N C D	rough fescue
Glyceria grandis	P N C D	American mannagrass
Helictotrichon hookeri	P N C I	spikeoat
Hesperochloa kingii	P N C D	spikefescue
Hierochloe odorata	P N C D	sweetgrass
Holcus lanatus	P I C V	velvetgrass
Hordeum brachyantherum	P N C I	meadow barley
H. jubatum	P N C I	foxtail barley
H. pusillum	A N C V	little barley
Koeleria cristata	P N C I	prairie junegrass
Lolium multiflorum	P I C V	Italian ryegrass
L. perenne	P I C V	perennial ryegrass
L. persicum	A I C V	Persian ryegrass
Melica bulbosa	P N C D	oniongrass
M. spectabilis	P N C D	purple oniongrass
Muhlenbergia asperifolia	P N W I	alkali muhly
M. cuspidata	P N W D	plains muhly
M. montana	P N W D	mountain muhly
M. racemosa	P N W I	marsh muhly
M. richardsonis	P N W I	mat muhly
Munroa squarrosa	A N W V	false buffalograss
Oryzopsis hymenoides	P N C D	Indian ricegrass
Panicum capillare	A N W V	witchgrass
P. virgatum	P N W D	switchgrass
Phalaris arundinacea	P N C D	reed canarygrass
P. canariensis	A I C V	canarygrass
Phleum alpinum	P N C D	alpine timothy
P. pratense	P I C V	timothy
Phragmites communis	P N W D	common reedgrass
Poa alpina	P N C D	alpine bluegrass
P. ampla	P N C D	big bluegrass
P. annua	A I C V	annual bluegrass
P. arida	P N C I	plains bluegrass
P. bulbosa	P I C V	bulbous bluegrass
P. canbyi	P N C D	Canby bluegrass
P. compressa	P I C V	Canada bluegrass
P. cusickii	P N C I	Cusick bluegrass
P. fendleriana	P N C D	muttongrass
P. juncifolia	P N C D	alkali bluegrass
P. nevadensis	P N C I	Nevada bluegrass
P. palustris	P I C V	fowl bluegrass
P. pratensis	P I C V	Kentucky bluegrass
P. sandbergii	P N C I	Sandberg bluegrass
Polypogon monspeliensis	A I C V	rabbitfootgrass
Puccinellia distans	P I C V	weeping alkaligrass
P. nuttalliana (P. airoides)	P N C D	Nuttall alkaligrass
Schedonnardus paniculatus	P N W I	tumblegrass
Schizachyrium scoparium	P N W D	little bluestem
Setaria lutescens	A I W V	yellow bristlegrass
S. viridis	A I W V	green bristlegrass
Sitanion hystrix	P N C I	bottlebrush squirreltail
Spartina gracilis	P N W D	alkali cordgrass
S. pectinata	P N W D	prairie cordgrass
Sporobolus airoides	P N W D	alkali sacaton
S. cryptandrus	P N W I	sand dropseed
Stipa columbiana	P N C D	Columbia needlegrass

	Longevity	Origin	Season	Gr. Response	
S. comata	P	N	C	I	needleandthread
S. lettermani	P	N	C	D	Letterman needlegrass
S. occidentalis	P	N	C	D	western needlegrass
S. richardsonii	P	N	C	D	Richardson needlegrass
S. spartea	P	N	C	D	porcupinegrass
S. viridula	P	N	C	D	green needlegrass
S. williamsii	P	N	C	D	Williams needlegrass
Trisetum spicatum	P	N	C	D	spike trisetum
Vulpia octoflora	A	N	C	V	sixweeks fescue

Grasslike Plants (Common Name)

	Longevity	Origin	Season	Gr. Response	
Carex eleocharis (C. stenophylla)	P	N	C	I	needleleaf sedge
Carex festivella	P	N	C	D	ovalhead sedge
Carex filifolia	P	N	C	I	threadleaf sedge
Carex geyeri	P	N	C	D	elk sedge
Carex heliophila	P	N	C	I	sun sedge
Carex nebraskensis	P	N	C	D	Nebraska sedge
Carex pensylvanica	P	N	C	I	yellow sedge
Eleocharis spp.	P	N	C	I	spikesedges
Juncus balticus	P	N	C	D	Baltic rush
Luzula glabrata	P	N	C	D	smooth woodrush

Grasslike Plants (Scientific Name)

	Longevity	Origin	Season	Gr. Response	
Baltic rush	P	N	C	D	*Juncus balticus*
Elk sedge	P	N	C	D	*Carex geyeri*
Nebraska sedge	P	N	C	D	*Carex nebraskensis*
Needleleaf sedge	P	N	C	I	*Carex eleocharis (C. stenophylla)*
Ovalhead sedge	P	N	C	D	*Carex festivella*
Smooth woodrush	P	N	C	D	*Luzula glabrata*
Spikesedges	P	N	C	I	*Eleocharis spp.*
Sun sedge	P	N	C	I	*Carex heliophila*
Threadleaf sedge	P	N	C	I	*Carex filifolia*
Yellow sedge	P	N	C	I	*Carex pensylvanica*

Forbs, Ferns and Mosses (Common Name)

	Longevity	Origin	Season	Gr. Response	
Alfalfa	P	I	C	V	*Medicago sativa*
Alkaline bladderpod	P	N	C	I	*Lesquerella alpina*
Alpine bluebell	P	N	C	I	*Mertensia alpina*
Alpine dustymaiden	P	N	C	I	*Chaenactis alpina*
Alpine forgetmenot	P	N	C	I	*Eritrichium elongatum (E. nanum)*
Alumroot	P	N	C	I	*Heuchera richardsonii*
American bistort	P	N	C	I	*Polygonum bistortoides*
American licorice	P	N	W	I	*Glycyrrhiza lepidota*
American vetch	P	N	C	D	*Vicia americana*
Andersons larkspur	P	N	C	I	*Delphinium andersonii*
Annual eriogonum	A	N	W	V	*Eriogonum annuum*
Annual sunflower	A	N	W	V	*Helianthus annuus*
Aromatic aster	P	N	W	I	*Aster oblongifolius*
Arrowleaf balsamroot	P	N	C	I	*Balsamorhiza sagittata*
Ballhead gilia	P	N	C	I	*Gilia congesta*
Ballhead sandwort	P	N	C	I	*Arenaria congesta*
Bastard toadflax	P	N	C	I	*Comandra pallida (C. umbellata)*
Beargrass	P	N	C	I	*Xerophyllus tenax*
Bessey pointvetch	P	N	C	I	*Oxytropis besseyi*
Bigbract verbena	P	N	W	I	*Verbena bracteata*
Biscuitroot	P	N	C	I	*Lomatium foeniculaceum*
Bitterroot	P	N	C	I	*Lewisia rediviva*
Black medic	A	I	C	V	*Medicago lupulina*
Black mustard	A	I	C	V	*Brassica nigra*
Blacksampson	P	N	W	D	*Echinacea angustifolia*
Blanketflower	P	N	W	I	*Gaillardia aristata*
Blue-eyed grass	P	N	C	I	*Sisyrinchium angustifolium*
Blue-eyed Mary	A	N	C	V	*Collinsia parviflora*
Blue flax	P	N	C	I	*Linum lewisii*
Blue lettuce	P	N	W	I	*Lactuca pulchella*
Blue mustard	A	I	C	V	*Chorispora tenella*
Brackenfern	P	N	X	I	*Pteridium aquilinum*
Breadroot scurfpea	P	N	C	D	*Psoralea esculenta*
Broadfruit mariposa	P	N	C	D	*Calochortus nitidus*
Broadleaf arnica	P	N	C	I	*Arnica latifolia*
Browns larkspur	P	N	C	I	*Delphinium brownii*
Bulb waterhemlock	P	N	W	I	*Cicuta bulbifera*
Bull thistle	B	I	W	V	*Cirsium vulgare*
Burclover	A	I	C	V	*Medicago hispida*
Burdock	B	I	W	V	*Arctium minus*
Burkes larkspur	P	N	C	I	*Delphinium burkei*
Butter and eggs	P	I	W	V	*Linaria vulgaris*
California falsehellebore	P	N	C	I	*Veratrum californicum*
Camas	P	N	C	I	*Camassia quamash*
Canada thistle	P	I	C	V	*Cirsium arvense*
Canada violet	P	N	C	I	*Viola canadensis*
Carolina draba	A	N	C	V	*Draba reptans*
Cattail	P	N	C	I	*Typha latifolia*

Charlock mustard	A I C V	*Brassica kaber*
Chickweed	A I C V	*Stellaria media*
Clasping pepperweed	A I C V	*Lepidium perfoliatum*
Clustered broomrape	P N C I	*Orobanche fasciculata*
Cocklebur	A N W V	*Xanthium strumarium*
Columbia monkshood	P N C I	*Aconitum columbianum*
Common eveningprimrose	B N C V	*Oenothera biennis*
Common horsetail	P N X I	*Equisetum arvense*
Common milkweed	P N W I	*Asclepias syriaca*
Common sainfoin	P I C V	*Onobrychis viciaefolia*
Common spiderwort	P N C D	*Tradescantia bracteata*
Common starlily	P N C I	*Leucocrinum montanum*
Common tansy	P I W V	*Tanacetum vulgare*
Cow parsnip	P N C D	*Heracleum lanatum*
Creeping silene	P N C I	*Silene repens*
Creeping white prairie aster	P N W I	*Aster falcatus*
Cudweed sagewort	P N W I	*Artemisia ludoviciana*
Curlycup gumweed	B N W V	*Grindelia squarrosa*
Curly dock	P I C V	*Rumex crispus*
Cutleaf balsamroot	P N C I	*Balsamorhiza macrophylla*
Cutleaf coneflower	P N W I	*Rudbeckia laciniata*
Cutleaf nightshade	A N W V	*Solanum triflorum*
Dalmation toadflax	P I W V	*Linaria dalmatica*
Dandelion (common)	P I C V	*Taraxacum officinale*
Dense clubmoss	P N X I	*Selaginella densa*
Desert alyssum	A N C V	*Alyssum desertorum*
Desert princesplume	P N C I	*Stanleya pinnata*
Desert wirelettuce	P N W I	*Stephanomeria runcinata*
Dotted gayfeather	P N W D	*Liatris punctata*
Douglas waterhemlock	P N W I	*Cicuta douglasii*
Downy Indianpaintbrush	P N C I	*Castilleja sessiliflora*
Drummond milkvetch	P N C I	*Astragalus drummondii*
Dustymaiden	B N C V	*Chaenactis douglasii*
Dwarf nettle	A I C V	*Urtica urens*
Eastern lomatium	P N C I	*Lomatium orientale*
Elk thistle	P N C I	*Cirsium foliosum* (*C. scariosum*)
Elephanthead	P N C I	*Pedicularis groenlandica*
Engelmann aster	P N W I	*Aster engelmannii*
Fairyslipper	P N C I	*Calypso bulbosa*
False pennyroyal	P N C I	*Hedeoma drummondii*
False prairie boneset	P N W D	*Kuhnia eupatorioides*
False solomonseal	P N C I	*Smilacina racemosa*
Fanweed	A I C V	*Thlaspi arvense*
Fernleaf lousewort	P N C I	*Pedicularis cystopteridifoli*
Few flowered buckwheat	P N W I	*Eriogonum pauciflorum* (*E. multiceps*)
Field bindweed	P I W V	*Convolvulus arvensis*
Field chickweed	P N C I	*Cerastium arvense*
Field fluffweed	A I W V	*Filago arvensis*
Field mint	P N W V	*Mentha arvensis*
Field sagewort	P N W I	*Artemisia campestris* (*A. canadensis*)
Field sowthistle	P I W V	*Sonchus arvensis*
Filaree	A I C V	*Erodium cicutarium*
Fineleaf hymenopappus	P N C I	*Hymenopappus filifolius*
Fireweed	P N C I	*Epilobium angustifolium*
Fivepetal blazingstar	B N W V	*Mentzelia laevicaulis*
Flannel mullein	B I W V	*Verbascum thapsus*
Foothill deathcamas	P N C I	*Zygadenus paniculatus*
Forgetmenot	P N C I	*Myosotis alpestris* (*M. sylvatica*)
Fuzzytongue penstemon	P N C I	*Penstemon eriantherus*
Geyer lark-pur	P N C I	*Delphinium geyeri*
Glacier lily	P N C I	*Erythronium grandiflorum*
Gland cinquefoil	P N C I	*Potentilla glandulosa*
Glaucus lark-pur	P N C I	*Delphinium glaucescens*
Goatweed	P I C V	*Hypericum perforatum*
Goldenweed	P N C I	*Machaeranthera grindeloide*
Gordon ivesia	P N C I	*Ivesia gordonii*
Green falsehellebore	P N C I	*Veratrum viride*
Green gentian	B N C V	*Frasera speciosa*
Green milkweed	P N W I	*Asclepias viridiflora*
Green sagewort	P N W I	*Artemisia dracunculus*
Groundcherry	P N W I	*Physalis longifolia*
Groundplum milkvetch	P N C D	*Astragalus crassicarpus*
Hairy goldenaster	P N W I	*Heterotheca villosa*
Halogeton	A I W V	*Halogeton glomeratus*
Heartleaf arnica	P N C I	*Arnica cordifolia*
Hemlock waterparsnip	P N W I	*Sium suave*
Hemp dogbane	P N W I	*Apocynum cannabinum*
Henbane	B I C V	*Hyoscyamus niger*
Hoary aster	B N W V	*Machaeranthera canescens*
Hoary balsamroot	P N C I	*Balsamorhiza incana*
Holboell rockcress	B N C V	*Arabis holboellii*
Hood phlox	P N C I	*Phlox hoodii*
Hook violet	P N C I	*Viola adunca*
Hooker fairybell	P N C I	*Disporum hookeri*
Hooker sandwort	P N C I	*Arenaria hookeri*
Horsemint	P N C I	*Monarda fistulosa*
Horseweed	A N W V	*Conyza canadensis*
Houndstongue	B I C V	*Cynoglossum officinale*
India mustard	A I C V	*Brassica juncea*
Jimsonweed	A N W V	*Datura stramonium*
Lambsquarters goosefoot	A I W V	*Chenopodium album*
Lambstongue groundsel	P N C I	*Senecio integerrimus*
Lanceleaf springbeauty	P N C I	*Claytonia lanceolata*
Lanceleaved sage	A N W V	*Salvia reflexa*
Leafy spurge	P I C V	*Euphorbia esula*
Leopard lily	P N C D	*Fritillaria atropurpurea*
Lewisia	P N C I	*Lewisia pygmaea*
Lily of the valley	P N C I	*Smilacina stellata*
Littleflower penstemon	P N C I	*Penstemon procerus*
Littlepod falseflax	A I C V	*Camelina microcarpa*
Longleaf phlox	P N C I	*Phlox longifolia*
Longstalk clover	P N C D	*Trifolium longipes*
Low fleabane	P N C I	*Erigeron pumilus*
Low larkspur	P N C I	*Delphinium bicolor*
Manyflowered aster	P N W I	*Aster ericoides*
Marsh arrowgrass	P N C I	*Triglochin palustris*
Marshelder sumpweed	A N W V	*Iva xanthifolia*
Marsh horsetail	P N S I	*Equisetum palustre*
Maximilians sunflower	P N W D	*Helianthus maximiliani*
Meadow deathcamas	P N C I	*Zygadenus venenosus* (*Z. intermedius*)
Minerscandle	B N C V	*Cryptantha bradburiana* (*C. celosioides*)
Missouri goldenrod	P N W I	*Solidago missouriensis*

Missouri milkvetch	P N C I	*Astragalus missouriensis*
Moss silene	P N C I	*Silene acaulis*
Mountain bluebell	P N C I	*Mertensia ciliata*
Mountain deathcamas	P N C I	*Zygadenus elegans*
Mountain gentian	P N W I	*Gentiana calycosa*
Mountain hollyhock	P N C I	*Iliamna rivularis*
Mountain ladyslipper	P N C I	*Cypripedium montanum*
Mountain sweetroot	P N C I	*Osmorhiza chilensis*
Mountain thermopsis	P N C I	*Thermopsis montana*
Mulesear wyethia	P N C I	*Wyethia amplexicaulis*
Musk thistle	B I C V	*Carduus nutans*
Narrowleaf gromwell	P N C I	*Lithospermum incisum*
Narrowleaf poisonvetch	P N C I	*Astragalus pectinatus*
Narrowleaved four-o'clock	P N C I	*Mirabilis linearis*
Narrowleaf Indianpaintbrush	P N C I	*Castilleja angustifolia*
Nelsons larkspur	P N C I	*Delphinium nelsonii*
		(D. nuttallianum)
Nettleleaf gianthyssop	P N C I	*Agastache urticifolia*
Nineleaf lomatium	P N C I	*Lomatium triternatum*
Nodding onion	P N C I	*Allium cernuum*
Northern bedstraw	P N W I	*Galium boreale*
Northern blue violet	P N C I	*Viola septentrionalis*
Northern sweetvetch	P N C D	*Hedysarum boreale*
Northwest cinquefoil	P N C I	*Potentilla gracilis*
Northwestern mariposa	P N C D	*Calochortus elegans*
Nuttall eveningprimrose	P N C I	*Oenothera nuttallii*
Nuttall evolvulus	P N W I	*Evolvulus nuttallianus*
		(E. pilosus)
Nuttall violet	P N C I	*Viola nuttallii*
Oakleaf goosefoot	A I W V	*Chenopodium glaucum*
Oblongleaf bluebell	P N C I	*Mertensia oblongifolia*
Orange arnica	P N C I	*Arnica fulgens*
Pacific lupine	P N C I	*Lupinus lepidus*
Pacific trillium	P N C I	*Trillium ovatum*
Pale agoseris	P N C D	*Agoseris glauca*
Pale alyssum	A N C V	*Alyssum alyssoides*
Parry townsendia	P N C I	*Townsendia parryi*
Pasqueflower	P N C I	*Anemone patens*
Pearly everlasting	P N C I	*Anaphalis margaritacea*
Pepperweed whitetop	P I C V	*Cardaria draba*
Pink microsteris	A N C V	*Microsteris gracilis*
Pink pyrola	P N C I	*Pyrola asarifolia*
Pinnate tansymustard	A N C V	*Descurainia pinnata*
Pinque hymenoxys	P N W I	*Hymenoxys richardsonii*
Plains bahia	P N C I	*Bahia oppositifolia*
Plains milkweed	P N W I	*Asclepias pumila*
Poison hemlock	B I W V	*Conium maculatum*
Polypody	P N S I	*Polypodium hesperium*
Poverty sumpweed	P N W I	*Iva axillaris*
Prairie coneflower	P N W I	*Ratibida columnifera*
Prairie groundsel	P N C I	*Senecio plattensis*
Prairie onion	P N C I	*Allium textile*
Prairie pepperweed	A N C V	*Lepidium densiflorum*
Prairiesmoke	P N C I	*Geum triflorum*
Prairie sunflower	A N W V	*Helianthus petiolaris*
Prairie thermopsis	P N C I	*Thermopsis rhombifolia*
Prickly lettuce	B I W V	*Lactuca serriola*
		(L. scariola)
Pricklypoppy	P N W I	*Argemone intermedia*
Pricklypoppy	A N W V	*Argemone polyanthemos*
Purple coneflower	P N W D	*Echinacea pallida*
Purple pointloco	P N C I	*Oxytropis lambertii*
Purple prairieclover	P N W D	*Petalostemon purpureum*
Pursh loco	P N C I	*Astragalus purshii*
Pursh seepweed	A N W V	*Suaeda depressa*
Queencup beadlily	P N C I	*Clintonia uniflora*
Red glasswort	A N W V	*Salicornia rubra*
Red kittentail	P N C I	*Besseya rubra*
Red monkeyflower	P N W I	*Mimulus lewisii*
Redroot pigweed	A I W V	*Amaranthus retroflexus*
Richardson geranium	P N C D	*Geranium richardsonii*
Ridgeseed spurge	A N C V	*Euphorbia glyptosperma*
Rocket larkspur	A I C V	*Delphinium ajacis*
Rocky Mountain beeplant	A N W V	*Cleome serrulata*
Rocky Mountain gayfeather	P N W D	*Liatris ligulistylis*
Rocky Mountain iris	P N C I	*Iris missouriensis*
Rose pussytoes	P N C I	*Antennaria rosea*
Rough pennyroyal	A N C V	*Hedeoma hispida*
Roundleaf harebell	P N C I	*Campanula rotundifolia*
Rush skeletonweed	P N W I	*Lygodesmia juncea*
Russian knapweed	P I W V	*Centaurea repens*
Russian thistle	A I W V	*Salsola kali*
Rusty lupine	A N C V	*Lupinus pusillus*
Sagebrush buttercup	P N C I	*Ranunculus glaberrimus*
Sagebrush mariposa	P N C D	*Calochortus macrocarpus*
Salsify	B I C V	*Tragopogon dubius*
Scarlet gaura	P N W I	*Gaura coccinea*
Scarlet gilia	B N C V	*Gilia aggregata*
Scarlet globemallow	P N C I	*Sphaeralcea coccinea*
Seaside arrowgrass	P N C I	*Triglochin maritima*
Segolily mariposa	P N C D	*Calochortus nuttallii*
Sheep sorrel	P I C V	*Rumex acetosella*
Shooting star	P N C I	*Dodecatheon pauciflorum*
Showy aster	P N W I	*Aster conspicuus*
Showy milkweed	P N W I	*Asclepias speciosa*
Shrubby eveningprimrose	P N C I	*Oenothera serrulata*
Silky lupine	P N C I	*Lupinus sericeus*
Silverleaf scurfpea	P N W I	*Psoralea argophylla*
Silverweed cinquefoil	P N C I	*Potentilla anserina*
Silvery lupine	P N C I	*Lupinus argenteus*
Slenderleaf collomia	A N C V	*Collomia linearis*
Slimflower scurfpea	P N W I	*Psoralea tenuiflora*
Slimleaf goosefoot	A N W V	*Chenopodium leptophyllum*
Slim larkspur	P N C I	*Delphinium depauperatum*
Small-leaf pussytoes	P N C I	*Antennaria parviflora*
Smooth aster	P N W I	*Aster laevis*
Smooth yellow violet	P N C I	*Viola glabella*
Sneezeweed	P N W I	*Helenium autumnale*
Snow-on-the-mountain	A N W V	*Euphorbia marginata*
Spearmint	P I W V	*Mentha spicata*
Spear saltbush	A N W V	*Atriplex patula*
Speckled loco	P N C I	*Astragalus lentiginosus*
Spiny cocklebur	A I W V	*Xanthium spinosum*
Spiny goldenweed	P N W I	*Happlopappus spinulosus*
Spotted knapweed	B I W V	*Centaurea maculosa*
Spreading dogbane	P N W I	*Apocynum androsaemifolium*
Spreading fleabane	B N C V	*Erigeron divergens*
Spur lupine	P N C I	*Lupinus laxiflorus*

Starflower	P N C I	*Lithophragma parviflora*
Steershead	P N C I	*Dicentra uniflora*
Stemless hymenoxys	P N C I	*Hymenoxys acaulis*
Stemless nailwort	P N C I	*Paronychia sessiliflora*
Sticky geranium	P N C D	*Geranium viscosissimum*
Stiff goldenrod	P N W I	*Solidago rigida*
Stiff sunflower	P N W D	*Helianthus rigidus*
Stiffstem flax	A N C V	*Linum rigidum*
Stinging nettle	P I C V	*Urtica dioica*
Stoneseed	P N C I	*Lithospermum ruderale*
Sugarbowl	P N C I	*Clematis hirsutissima*
Suksdorfs broomrape	P N C I	*Orobanche ludoviciana*
Sulfur eriogonum	P N C I	*Eriogonum umbellatum*
Sulfur lupine	P N C I	*Lupinus sulphureus*
Summer cypress	A I W V	*Kochia scoparia*
Sweetscented bedstraw	P N W I	*Galium triflorum*
Tailcup lupine	P N C I	*Lupinus caudatus*
Tall larkspur	P N C I	*Delphinium occidentale*
Tapertip hawksbeard	P N C I	*Crepis acuminata*
Tenpetal blazingstar	B N W V	*Mentzelia decapetala*
Thickleaf groundsel	P N W I	*Senecio crassulus*
Thinleaved owlclover	A N C V	*Orthocarpus tenuifolius*
Threadleaf phacelia	A N C V	*Phacelia linearis*
Threeleaved milkvetch	P N C I	*Astragalus gilviflorus*
Timber milkvetch	P N C I	*Astragalus miser*
Toothed microseris	P N C I	*Microseris cuspidata*
Tuberous sweetpea	P N C D	*Lathyrus tuberosus*
Tufted eveningprimrose	P N C I	*Oenothera caespitosa*
Tufted milkvetch	P N C I	*Astragalus spatulatus*
Tumble mustard	A I C V	*Sisymbrium altissimum*
Tumbleweed pigweed	A N W V	*Amaranthus graecizans*
Twin arnica	P N C I	*Arnica sororia*
Twinleaf bedstraw	A N C V	*Galium bifolium*
Twogrooved milkvetch	P N C I	*Astragalus bisulcatus*
Umbrella buckwheat	P N C I	*Eriogonum heracleoides*
Velvet lupine	P N C I	*Lupinus leucophyllus*
Velvety goldenrod	P N W I	*Solidago mollis*
Virginia strawberry	P N C I	*Fragaria virginiana*
Wartberry fairybell	P N C I	*Disporum trachycarpum*
Washington lupine	P N C I	*Lupinus polyphyllus*
Waterleaf	P N C I	*Hydrophyllum capitatum*
Wavyleaf thistle	B N W V	*Cirsium undulatum*
Waxleaf penstemon	P N C I	*Penstemon nitidus*
Western coneflower	P N C I	*Rudbeckia occidentalis*
Western goldenrod	P N W I	*Solidago occidentalis*
Western meadow aster	P N W I	*Aster campestris*
Western meadowrue	P N C I	*Thalictrum occidentale*
Western ragweed	P N W I	*Ambrosia psilostachya*
Western rockjasmine	A N C V	*Androsace occidentalis*
Western roundleaved violet	P N C I	*Viola orbiculata*
Western stickseed	A N C V	*Lappula redowskii*
Western wallflower	B N C V	*Erysimum asperum*
Western yarrow	P N W I	*Achillea lanulosa* (*A. millefolium*)
White hawkweed	P N W D	*Hieracium albiflorum*
White milkwort	P N C I	*Polygala alba*
White mustard	A I C V	*Brassica hirta*
White penstemon	P N C I	*Penstemon albidus*
White phlox	P N C I	*Phlox multiflora*

White pointloco	P N C I	*Oxytropis sericea*
White prairieclover	P N W D	*Petalostemon candidum*
Whitestem eveningprimrose	A N C V	*Oenothera albicaulis*
White sweetclover	B I C V	*Melilotus alba*
White wild sweetpea	P N C D	*Lathyrus ochroleucus*
White wyethia	P N C I	*Wyethia helianthoides*
Whorled milkweed	P N W I	*Asclepias verticillata*
Wild hyacinth	P N C D	*Brodiaea douglasii*
Wild parsley	P N C I	*Musineon divaricatum*
Woodland pinedrops	P N C I	*Pterospora andromedea*
Woodland sage	P I W V	*Salvia sylvestris*
Woodland strawberry	P N C I	*Fragaria vesca*
Wood lily	P N C D	*Lilium philadelphicum*
Woolly eriophyllum	P N C I	*Eriophyllum lanatum*
Woolly groundsel	P N C I	*Senecio canus*
Woolly plantain	A N C V	*Plantago patagonica* (*P. purshii*)
Wyeth lupine	P N C I	*Lupinus wyethii*
Wyoming Indianpaintbrush	P N C I	*Castilleja linariaefolia*
Yampa	P N W I	*Perideridia gairdneri*
Yellow beeplant	A N W V	*Cleome lutea*
Yellowbell	P N C I	*Fritillaria pudica*
Yellow buckwheat	P N C I	*Eriogonum flavum*
Yellow Indianpaintbrush	P N C I	*Castilleja flava*
Yellow monkeyflower	P N W I	*Mimulus guttatus*
Yellow owlclover	A N C V	*Orthocarpus luteus*
Yellow skunkcabbage	P N C I	*Lysichitum americanum*
Yellow starthistle	A I W V	*Centaurea solstitialis*
Yellow stonecrop	P N C I	*Sedum stenopetalum*
Yellow sweetclover	B I C V	*Melilotus officinalis*

Forbs, Ferns and Mosses (Scientific Name)

	Longevity Origin Season Gr. Response	
Achillea lanulosa (*A. millefolium*)	P N W I	western yarrow
Aconitum columbianum	P N C I	Columbia monkshood
Agastache urticifolia	P N C I	nettleleaf gianthyssop
Agoseris glauca	P N C D	pale agoseris
Allium cernuum	P N C I	nodding onion
A. textile	P N C I	prairie onion
Alyssum alyssoides	A N C V	pale alyssum
A. desertorum	A N C V	desert alyssum
Amaranthus graecizans	A N W V	tumbleweed pigweed
A. retroflexus	A I W V	redroot pigweed
Ambrosia psilostachya	P N W I	western ragweed

Anaphalis margaritacea	P N C I	pearly everlasting
Androsace occidentalis	A N C V	western rockjasmine
Anemone patens	P N C I	pasqueflower
Antennaria parviflora	P N C I	small-leaf pussytoes
A. rosea	P N C I	rose pussytoes
Apocynum androsaemifolium	P N W I	spreading dogbane
A. cannabinum	P N W I	hemp dogbane
Arabis holboellii	B N C V	Holboell rockcress
Arctium minus	B I W V	burdock
Arenaria congesta	P N C I	ballhead sandwort
A. hookeri	P N C I	Hooker sandwort
Argemone intermedia	P N W I	pricklypoppy
A. polyanthemos	A N W V	pricklypoppy
Arnica cordifolia	P N C I	heartleaf arnica
A. fulgens	P N C I	orange arnica
A. latifolia	P N C I	broadleaf arnica
A. sororia	P N C I	twin arnica
Artemisia campestris	P N W I	field sagewort
(A. canadensis)		
A. dracunculus	P N W I	green sagewort
A. ludoviciana	P N W I	cudweed sagewort
Asclepias pumila	P N W I	plains milkweed
A. speciosa	P N W I	showy milkweed
A. syriaca	P N W I	common milkweed
A. verticillata	P N W I	whorled milkweed
A. viridiflora	P N W I	green milkweed
Aster campestris	P N W I	western meadow aster
A. conspicuus	P N W I	showy aster
A. engelmannii	P N W I	Engelmann aster
A. ericoides	P N W I	manyflowered aster
A. falcatus	P N W I	creeping white prairie aster
A. laevis	P N W I	smooth aster
A. oblongifolius	P N W I	aromatic aster
Astragalus bisulcatus	P N C I	twogrooved milkvetch
A. crassicarpus	P N C D	groundplum milkvetch
A. drummondii	P N C I	Drummond milkvetch
A. gilviflorus	P N C I	threeleaved milkvetch
A. lentiginosus	P N C I	speckled loco
A. miser	P N C I	timber milkvetch
A. missouriensis	P N C I	Missouri milkvetch
A. pectinatus	P N C I	narrowleaf poisonvetch
A. purshii	P N C I	Pursh loco
A. spatulatus	P N C I	tufted milkvetch
Atriplex patula	A N W V	spear saltbush
Bahia oppositifolia	P N C I	plains bahia
Balsamorhiza incana	P N C I	hoary balsamroot
B. macrophylla	P N C I	cutleaf balsamroot
B. sagittata	P N C I	arrowleaf balsamroot
Besseya rubra	P N C I	red kittentail
Brassica hirta	A I C V	white mustard
B. juncea	A I C V	India mustard
B. kaber	A I C V	charlock mustard
B. nigra	A I C V	black mustard
Brodiaea douglasii	P N C D	wild hyacinth
Calochortus elegans	P N C D	northwestern mariposa
C. macrocarpus	P N C D	sagebrush mariposa
C. nitidus	P N C D	broadfruit mariposa
C. nuttallii	P N C D	segolily mariposa
Calypso bulbosa	P N C I	fairyslipper
Camassia quamash	P N C I	camas
Camelina microcarpa	A I C V	littlepod falseflax
Campanula rotundifolia	P N C I	roundleaf harebell
Cardaria draba	P I C V	pepperweed whitetop
Carduus nutans	B I C V	musk thistle
Castilleja angustifolia	P N C I	narrowleaf Indianpaintbrush
C. flava	P N C I	yellow Indianpaintbrush
C. linariaefolia	P N C I	Wyoming Indianpaintbrush
C. sessiliflora	P N C I	downy Indianpaintbrush
Centaurea maculosa	B I W V	spotted knapweed
C. repens	P I W V	Russian knapweed
C. solstitialis	A I W V	yellow starthistle
Cerastium arvense	P N C I	field chickweed
Chaenactis alpina	P N C I	alpine dustymaiden
C. douglasii	B N C V	dustymaiden
Chenopodium album	A I W V	lambsquarters goosefoot
C. glaucum	A I W V	oakleaf goosefoot
C. leptophyllum	A N W V	slimleaf goosefoot
Chorispora tenella	A I C V	blue mustard
Cicuta bulbifera	P N W I	bulb waterhemlock
C. douglasii	P N W I	Douglas waterhemlock
Cirsium arvense	P I C V	Canada thistle
C. foliosum	P N C I	elk thistle
(C. scariosum)		
C. undulatum	B N W V	wavyleaf thistle
C. vulgare	B I W V	bull thistle
Claytonia lanceolata	P N C I	lanceleaf springbeauty
Clematis hirsutissima	P N C I	sugarbowl
Cleome lutea	A N W V	yellow beeplant
C. serrulata	A N W V	Rocky Mountain beeplant
Clintonia uniflora	P N C I	queencup beadlily
Collinsia parviflora	A N C V	blue-eyed Mary
Collomia linearis	A N C V	slenderleaf collomia
Comandra pallida	P N C I	bastard toadflax
(C. umbellata)		
Conium maculatum	B I W V	poison hemlock
Convolvulus arvensis	P I W V	field bindweed
Conyza canadensis	A N W V	horseweed
Crepis acuminata	P N C I	tapertip hawksbeard
Crypthantha bradburiana	B N C V	minerscandle
(C. celosioides)		
Cynoglossum officinale	B I C V	houndstongue
Cypridedium montanum	P N C I	mountain ladyslipper
Datura stramonium	A N W V	Jimsonweed
Delphinium ajacis	A I C V	rocket larkspur
D. andersonii	P N C I	Andersons larkspur
D. bicolor	P N C I	low larkspur
D. brownii	P N C I	Browns larkspur
D. burkei	P N C I	Burkes larkspur
D. depauperatum	P N C I	slim larkspur
D. geyeri	P N C I	Geyer larkspur
D. glaucescens	P N C I	glaucus larkspur
D. nelsonii	P N C I	Nelsons larkspur
(D. nuttallianum)		
D. occidentale	P N C I	tall larkspur
Descurainia pinnata	A N C V	pinnate tansymustard
Dicentra uniflora	P N C I	steershead
Disporum hookeri	P N C I	Hooker fairybell
D. trachycarpum	P N C I	wartberry fairybell

Dodecatheon pauciflorum	P N C I	shooting star
Draba reptans	A N C V	Carolina draba
Echinacea angustifolia	P N W D	blacksampson
E. pallida	P N W D	purple coneflower
Epilobium angustifolium	P N C I	fireweed
Equisetum arvense	P N N I	common horsetail
E. palustre	P N N I	marsh horsetail
Erigeron divergens	B N C V	spreading fleabane
E. pumilus	P N C I	low fleabane
Eriogonum annum	A N W V	annual eriogonum
E. flavum	P N C I	yellow buckwheat
E. heracleoides	P N C I	umbrella buckwheat
E. pauciflorum	P N W I	few-flowered buckwheat
(E. multiceps)		
E. umbellatum	P N C I	sulfur eriogonum
Eriophyllum lanatum	P N C I	woolly eriophyllum
Eritrichium elongatum	P N C I	alpine forgetmenot
(E. nanum)		
Erodium cicutarium	A I C V	filaree
Erysimum asperum	B N C V	western wallflower
Erythronium grandiflorum	P N C I	glacier lily
Euphorbia esula	P I C V	leafy spurge
E. glyptosperma	A N C V	ridgeseed spurge
E. marginata	A N W V	snow-on-the-mountain
Evolvulus nuttallianus	P N W I	Nuttall evolvulus
(E. pilosus)		
Filago arvensis	A I W V	field fluffweed
Fragaria vesca	P N C I	woodland strawberry
F. virginiana	P N C I	Virginia strawberry
Frasera speciosa	B N C V	green gentian
Fritillaria atropurpurea	P N C D	leopard lily
F. pudica	P N C I	yellowbell
Gaillardia aristata	P N W I	blanketflower
Galium bifolium	A N C V	twinleaf bedstraw
G. boreale	P N W I	northern bedstraw
G. triflorum	P N W I	sweetscented bedstraw
Gaura coccinea	P N W I	scarlet gaura
Gentiana calycosa	P N W I	mountain gentian
Geranium richardsonii	P N C D	Richardson geranium
G. viscosissimum	P N C D	sticky geranium
Geum triflorum	P N C I	prairiesmoke
Gilia aggregata	B N C V	scarlet gilia
G. congesta	P N C I	ballhead gilia
Glycyrrhiza lepidota	P N W I	American licorice
Grindelia squarrosa	B N W V	curlycup gumweed
Halogeton glomeratus	A I W V	halogeton
Haplopappus spinulosus	P N W I	spiny goldenweed
Hedeoma drummondii	P N C I	false pennyroyal
H. hispida	A N C V	Rough pennyroyal
Hedysarum boreale	P N C D	northern sweetvetch
Helenium autumnale	P N W I	sneezeweed
Helianthus annuus	A N W V	annual sunflower
H. maximiliani	P N W D	Maximilians sunflower
H. petiolaris	A N W V	prairie sunflower
H. rigidus	P N W D	stiff sunflower
Heracleum lanatum	P N C D	cow parsnip
Heterotheca villosa	P N W I	hairy goldenaster
Heuchera richardsonii	P N C I	alumroot
Hieracium albiflorum	P N W D	white hawkweed
Hydrophyllum capitatum	P N C I	waterleaf
Hymenopappus filifolius	P N C I	fineleaf hymenopappus
Hymenoxys acaulis	P N C I	stemless hymenoxys
H. richardsonii	P N W I	pingue hymenoxys
Hyoscyamus niger	B I C V	henbane
Hypericum perforatum	P I C V	goatweed
Iliamna rivularis	P N C I	mountain hollyhock
Iris missouriensis	P N C I	Rocky Mountain iris
Iva axillaris	P N W I	poverty sumpweed
I. xanthifolia	A N W V	marshelder sumpweed
Ivesia gordonii	P N C I	Gordon ivesia
Kochia scoparia	A I W V	summer cypress
Kuhnia eupatorioides	P N W D	false prairie boneset
Lactuca pulchella	P N W I	blue lettuce
L. serriola	B I W V	prickly lettuce
(L. scariola)		
Lappula redowskii	A N C V	western stickseed
Lathyrus ochroleucus	P N C D	white wild sweetpea
L. tuberosus	P N C D	tuberous sweetpea
Lepidium densiflorum	A N C V	prairie pepperweed
L. perfoliatum	A I C V	clasping pepperweed
Lesquerella alpina	P N C I	alkaline bladderpod
Leucocrinum montanum	P N C I	common starlily
Lewisia pygmaea	P N C I	lewisia
L. rediviva	P N C I	bitterroot
Liatris ligulistylis	P N W D	Rocky Mountain gayfeather
L. punctata	P N W D	dotted gayfeather
Lilium philadelphicum	P N C D	wood lily
Linaria dalmatica	P I W V	dalmation toadflax
L. vulgaris	P I W V	butter and eggs
Linum lewisii	P N C I	blue flax
L. rigidum	A N C V	stiffstem flax
Lithophragma parviflora	P N C I	starflower
Lithospermum incisum	P N C I	narrowleaf gromwell
L. ruderale	P N C I	stoneseed
Lomatium foeniculaceum	P N C I	biscuitroot
L. orientale	P N C I	eastern lomatium
L. triternatum	P N C I	nineleaf lomatium
Lupinus argenteus	P N C I	silvery lupine
L. caudatus	P N C I	tailcup lupine
L. laxiflorus	P N C I	spur lupine
L. lepidus	P N C I	Pacific lupine
L. polyphyllus	P N C I	velvet lupine
L. leucophyllus	P N C I	velvet lupine
L. polyphyllus	P N C I	Washington lupine
L. pusillus	A N C V	rusty lupine
L. sericeus	P N C I	silky lupine
L. sulphureus	P N C I	sulfur lupine
L. wyethii	P N C I	Wyeth lupine
Lygodesmia juncea	P N W I	rush skeletonweed
Lysichitum americanum	P N C I	yellow skunkcabbage
Machaeranthera canescens	B N W V	hoary aster
M. grindelioides	P N C I	goldenweed
Medicago hispida	A I C V	burclover
M. lupulina	A I C V	black medic
M. sativa	P I C V	alfalfa
Melilotus alba	B I C V	white sweetclover
M. officinalis	B I C V	yellow sweetclover
Mentha arvensis	P N W V	field mint

M. spicata	P I W V	spearmint
Mentzelia decapetala	B N W V	tenpetal blazingstar
M. laevicaulis	B N W V	fivepetal blazingstar
Mertensia alpina	P N C I	alpine bluebell
M. ciliata	P N C I	mountain bluebell
M. oblongifolia	P N C I	oblongleaf bluebell
Microseris cuspidata	P N C I	toothed microseris
Microsteris gracilis	A N C V	pink microsteris
Mimulus guttatus	P N W I	yellow monkeyflower
M. lewisii	P N W I	red monkeyflower
Mirabilis linearis	P N C I	narrowleaved four-o'clock
Monarda fistulosa	P N C I	horsemint
Musineon divaricatum	P N C I	wild parsley
Myosotis alpestris (*M. sylvatica*)	P N C I	forgetmenot
Oenothera albicaulis	A N C V	whitestem eveningprimrose
O. biennis	B N C V	common eveningprimrose
O. caespitosa	P N C I	tufted eveningprimrose
O. nuttallii	P N C I	Nuttall eveningprimrose
Onobrychis viciaefolia	P I C V	common sainfoin
Orobanche fasciculata	P N C I	clustered broomrape
O. ludoviciana	P N C I	Suksdorf's broomrape
Orthocarpus luteus	A N C V	yellow owlclover
O. tenuifolius	A N C V	thinleaved owlclover
Osmorhiza chilensis	P N C I	mountain sweetroot
Oxytropis besseyi	P N C I	Bessey pointvetch
O. lambertii	P N C I	purple pointloco
O. sericea	P N C I	white pointloco
Paronychia sessiliflora	P N C I	stemless nailwort
Pedicularis cystopteridifolia	P N C I	fernleaf lousewort
P. groenlandica	P N C I	elephanthead
Penstemon albidus	P N C I	white penstemon
P. eriantherus	P N C I	fuzzytongue penstemon
P. nitidus	P N C I	waxleaf penstemon
P. procerus	P N C I	littleflower penstemon
Perideridia gairdneri	P N W I	yampa
Petalostemon candidum	P N W D	white prairieclover
P. purpureum	P N W D	purple prairieclover
Phacelia linearis	A N C V	threadleaf phacelia
Phlox hoodii	P N C I	Hood phlox
P. longifolia	P N C I	longleaf phlox
P. multiflora	P N C I	white phlox
Physalis longifolia	P N W I	groundcherry
Plantago patagonica (*P. purshii*)	A N C V	woolly plantain
Polygala alba	P N C I	white milkwort
Polygonum bistortoides	P N C I	American bistort
Polypodium hesperium	P N S I	polypody
Potentilla anserina	P N C I	silverweed cinquefoil
P. glandulosa	P N C I	gland cinquefoil
P. gracilis	P N C I	northwest cinquefoil
Psoralea argophylla	P N W I	silverleaf scurfpea
P. esculenta	P N C D	breadroot scurfpea
P. tenuiflora	P N W I	slimflower scurfpea
Pteridium aquilinum	P N X I	brackenfern
Pterospora andromedea	P N C I	woodland pinedrops
Pyrola asarifolia	P N C I	pink pyrola
Ranunculus glaberrimus	P N C I	sagebrush buttercup
Ratibida columnifera	P N W I	prairie coneflower
Rudbeckia laciniata	P N W I	cutleaf coneflower
R. occidentalis	P N C I	western coneflower
Rumex acetosella	P I C V	sheep sorrel
R. crispus	P I C V	curly dock
Salicornia rubra	A N W V	red glasswort
Salsola iberica	A I W V	Russian thistle
Salvia reflexa	A N W V	lanceleaved sage
S. sylvestris	P I W V	woodland sage
Sedum stenopetalum	P N C I	yellow stonecrop
Selaginella densa	P N X I	dense clubmoss
Senecio canus	P N C I	woolly groundsel
S. crassulus	P N W I	thickleaf groundsel
S. integerrimus	P N C I	lambstongue groundsel
S. plattensis	P N C I	prairie groundsel
Silene acaulis	P N C I	moss silene
S. repens	P N C I	creeping silene
Sisymbrium altissimum	A I C V	tumble mustard
Sisyrinchium angustifolium	P N C I	blue-eyed grass
Sium suave	P N W I	hemlock waterparsnip
Smilacina racemosa	P N C I	false solomonseal
S. stellata	P N C I	lily of the valley
Solanum triflorum	A N W V	cutleaf nightshade
Solidago missouriensis	P N W I	Missouri goldenrod
S. mollis	P N W I	velvety goldenrod
S. occidentalis	P N W I	western goldenrod
S. rigida	P N W I	stiff goldenrod
Sonchus arvensis	P I W V	field sowthistle
Sphaeralcea coccinea	P N C I	scarlet globemallow
Stanleya pinnata	P N C I	desert princesplum
Stellaria media	A I C V	chickweed
Stephanomeria runcinata	P N W I	desert wirelettuce
Suaeda depressa	A N W V	Pursh seepweed
Tanacetum vulgare	P I W V	common tansy
Taraxacum officinale	P I C V	dandelion (common)
Thalictrum occidentale	P N C I	western meadowrue
Thermopsis montana	P N C I	mountain thermopsis
T. rhombifolia	P N C I	prairie thermopsis
Thlaspi arvense	A I C V	fanweed
Townsendia parryi	P N C I	Parry townsendia
Tradescantia bracteata	P N C D	common spiderwort
Tragopogon dubius	B I C V	salsify
Trifolium longipes	P N C D	longstalk clover
Triglochin maritima	P N C I	seaside arrowgrass
T. palustris	P N C I	marsh arrowgrass
Trillium ovatum	P N C I	Pacific trillium
Typha latifolia	P N C I	cattail
Urtica dioica	P I C V	stinging nettle
U. urens	A I C V	dwarf nettle
Veratrum californicum	P N C I	California falsehellebore
V. viride	P N C I	green falsehellebore
Verbascum thapsus	B I W V	flannel mullein
Verbena bracteata	P N W I	bigbract verbena
Vicia americana	P N C D	American vetch
Viola adunca	P N C I	hook violet
V. canadensis	P N C I	Canada violet
V. glabella	P N C I	smooth yellow violet
V. nuttallii	P N C I	Nuttall violet
V. orbiculata	P N C I	western roundleaved violet
V. septentrionalis	P N C I	northern blue violet

Wyethia amplexicaulis	P	N	C	I	mulesear wyethia
W. helianthoides	P	N	C	I	white wyethia
Xanthium spinosum	A	I	W	V	spiny cocklebur
X. strumarium	A	N	W	V	cocklebur
Xerophyllum tenax	P	N	C	I	beargrass
Zygadenus elegans	P	N	C	I	mountain deathcamas
Z. paniculatus	P	N	C	I	foothill deathcamas
Z. venenosus (*Z. intermedius*)	P	N	C	I	meadow deathcamas

Cactus (Common Name)

	Longevity	Origin	Season	Gr. Response	
Brittle pricklypear	P	N	C	I	*Opuntia fragilis*
Pink pincushion cactus	P	N	C	I	*Mammillaria vivipara*
Pricklypear	P	N	C	I	*Opuntia polyacantha*
Yellow pincushion cactus	P	N	C	I	*Mammillaria missouriensis*

Cactus (Scientific Name)

	Longevity	Origin	Season	Gr. Response	
Mammillaria missouriensis	P	N	C	I	yellow pincushion cactus
M. vivipara	P	N	C	I	pink pincushion cactus
Opuntia fragilis	P	N	C	I	brittle pricklypear
O. polyacantha	P	N	C	I	pricklypear

Half-Shrubs, Shrubs, Trees and Vines (Common Name)

	Longevity	Origin	Season	Gr. Response	
Alderleaf buckthorn	P	N	C	I	*Rhamnus alnifolia*
Alpine larch	P	N	X	X	*Larix lyallii*
American elm	P	N	C	D	*Ulmus americana*
American kochia	P	N	W	I	*Kochia americana*
American plum	P	N	C	D	*Prunus americana*
Big sagebrush	P	N	W	I	*Artemisia tridentata*
Birchleaf mountainmahogany	P	N	C	D	*Cercocarpus montanus*
Birdfoot sagebrush	P	N	W	I	*Artemisia pedatifida*
Bitterbrush	P	N	C	D	*Purshia tridentata*
Bitter cherry	P	N	C	I	*Prunus emarginata*
Black cottonwood	P	N	C	D	*Populus trichocarpa*
Black elderberry	P	N	C	D	*Sambucus melanocarpa* (*S. racemosa*)
Black hawthorn	P	N	C	I	*Crataegus douglasii*
Black sagebrush	P	N	W	I	*Artemisia nova*
Blue elderberry	P	N	C	D	*Sambucus caerulea*
Boxelder	P	N	C	D	*Acer negundo*
Broom snakeweed	P	N	W	I	*Xanthocephalum sarothrae*
Bud sagebrush	P	N	C	I	*Artemisia spinescens*
Cascara buckthorn	P	N	C	D	*Rhamnus purshiana*
Chokecherry	P	N	C	D	*Prunus virginiana*
Columbia hawthorn	P	N	C	I	*Crataegus columbiana*
Common juniper	P	N	X	X	*Juniperus communis*
Common snowberry	P	N	C	I	*Symphoricarpos albus*
Coralberry	P	N	C	I	*Symphoricarpos orbiculatus*
Creeping juniper	P	N	X	X	*Juniperus horizontalis*
Curlleaf mountainmahogany	P	N	C	D	*Cercocarpus ledifolius*
Devilsclub	P	N	C	I	*Oplopanax horridum*
Douglas fir	P	N	X	X	*Pseudotsuga menziesii*
Engelmann spruce	P	N	X	X	*Picea engelmannii*
Fourwing saltbush	P	N	W	D	*Atriplex canescens*
Fringed sagewort	P	N	W	I	*Artemisia frigida*
Golden currant	P	N	C	I	*Ribes aureum*
Grand fir	P	N	X	X	*Abies grandis*
Granite gilia	P	N	C	I	*Leptodactylon pungens*
Gray horsebrush	P	N	W	I	*Tetradymia canescens*
Greasewood	P	N	C	D	*Sarcobatus vermiculatus*
Green ash	P	N	C	D	*Fraxinus pennsylvanica*
Green rabbitbrush	P	N	W	I	*Chrysothamnus viscidiflorus*
Grouse whortleberry	P	N	C	I	*Vaccinium scoparium*
Kinnikinnick	P	N	C	I	*Arctostaphylos uva-ursi*
Limber pine	P	N	X	X	*Pinus flexilis*
Lodgepole pine	P	N	X	X	*Pinus contorta*
Low sagebrush	P	N	W	I	*Artemisia arbuscula*
Mountain ash	P	N	C	I	*Sorbus scopulina*
Mountain boxelder	P	N	C	I	*Alnus sinuata*
Mountain hemlock	P	N	X	X	*Tsuga mertensiana*
Mountain spiraea	P	N	C	I	*Spiraea splendens* (*S. densifolia*)

Myrtle pachistima	P N C D	*Pachistima myrsinites*
Myrtle whortleberry	P N C I	*Vaccinium myrtillus*
Narrowleaf cottonwood	P N C D	*Populus angustifolia*
Ninebark	P N C I	*Physocarpus malvaceus*
Nootka rose	P N C I	*Rosa nutkana*
Nuttall saltbush	P N W D	*Atriplex nuttallii* (*A. gardneri*)
Oceanspray	P N C I	*Holodiscus discolor*
Oregongrape	P N C D	*Berberis repens*
Pacific yew	P N C I	*Taxus brevifolia*
Paper birch	P N C I	*Betula papyrifera*
Pin cherry	P N C D	*Prunus pensylvanica*
Pink spiraea	P N C I	*Spiraea douglasii*
Plains cottonwood	P N C D	*Populus deltoides*
Poison ivy	P N C I	*Rhus radicans*
Ponderosa pine	P N X X	*Pinus ponderosa*
Prairie rose	P N C I	*Rosa arkansana*
Princes pine pipsissewa	P N C I	*Chimaphila umbellata*
Quaking aspen	P N C D	*Populus tremuloides*
Red mountainheath	P N C I	*Phyllodoce empetriformis*
Redosier dogwood	P N C D	*Cornus stolonifera*
Red raspberry	P N C I	*Rubus idaeus*
Redstem ceanothus	P N C D	*Ceanothus sanguineus*
Rock clematis	P N C I	*Clematis columbiana*
Rocky Mountain juniper	P N X X	*Juniperus scopulorum*
Rocky Mountain maple	P N C D	*Acer glabrum*
Rubber rabbitbrush	P N W I	*Chrysothamnus nauseosus*
Russet buffaloberry	P N C I	*Shepherdia canadensis*
Russian olive	P I C V	*Elaeagnus angustifolia*
Serviceberry	P N C D	*Amelanchier alnifolia*
Shadscale	P N C I	*Atriplex confertifolia*
Shrubby cinquefoil	P N C I	*Potentilla fruticosa*
Silverberry	P N C I	*Elaeagnus commutata*
Silver buffaloberry	P N C I	*Shepherdia argentea*
Silver sagebrush	P N W I	*Artemisia cana*
Skunkbush sumac	P N C D	*Rhus trilobata*
Slenderbrush eriogonum	P N C D	*Eriogonum microthecum*
Smooth sumac	P N C D	*Rhus glabra*
Snowbrush ceanothus	P N C I	*Ceanothus velutinus*
Soapweed	P N C I	*Yucca glauca*
Squaw currant	P N C I	*Ribes cereum*
Sticky currant	P N C I	*Ribes viscosissimum*
Subalpine fir	P N X X	*Abies lasiocarpa*
Syringa	P N C I	*Philadelphus lewisii*
Thimbleberry	P N C I	*Rubus parviflorus*
Thinleaf alder	P N C I	*Alnus tenuifolia* (*A. incana*)
Thinleaved huckleberry	P N C I	*Vaccinium membranaceum*
Threetip sagebrush	P N W I	*Artemisia tripartita*
Twinberry honeysuckle	P N C I	*Lonicera involucrata*
Twinflower	P N C I	*Linnaea borealis*
Utah honeysuckle	P N C I	*Lonicera utahensis*
Utah juniper	P N X X	*Juniperus osteosperma*
Water birch	P N C I	*Betula occidentalis*
Western hemlock	P N X X	*Tsuga heterophylla*
Western larch	P N X X	*Larix occidentalis*
Western redcedar	P N X X	*Thuja plicata*
Western snowberry	P N C I	*Symphoricarpos occidentalis*
Western white pine	P N X X	*Pinus monticola*
Whitebark pine	P N X X	*Pinus albicaulis*
Whitebark raspberry	P N C I	*Rubus leucodermis*
White clematis	P N W I	*Clematis ligusticifolia*
White mountain avens	P N C I	*Dryas octopetala*
White spiraea	P N C I	*Spiraea betulifolia*
White spruce	P N X X	*Picea glauca*
Whitestemmed gooseberry	P N C I	*Ribes inerme*
Whortleleaf snowberry	P N C I	*Symphoricarpos oreophilus*
Willow	P N C D	*Salix spp.*
Winterfat	P N W D	*Ceratoides lanata*
Woods rose	P N C I	*Rosa woodsii*
Yellow mountainheath	P N C I	*Phyllodoce glanduliflora*

Half-Shrubs, Shrubs, Trees and Vines (Scientific Name)

	Longevity Origin Season Gr. Response	
Abies grandis	P N X X	grand fir
A. lasiocarpa	P N X X	subalpine fir
Acer glabrum	P N C D	Rocky Mountain maple
A. negundo	P N C D	boxelder
Alnus sinuata	P N C I	mountain boxelder
A. tenuifolia (*A. incana*)	P N C I	thinleaf alder
Amelanchier alnifolia	P N C D	serviceberry
Arctostaphylos uva-ursi	P N C I	Kinnikinnick
Artemisia arbuscula	P N W I	low sagebrush
A. cana	P N W I	silver sagebrush
A. frigida	P N W I	fringed sagewort
A. nova	P N W I	black sagebrush
A. pedatifida	P N W I	bird foot sagebrush
A. spinescens	P N C I	bud sagebrush
A. tridentata	P N W I	big sagebrush
A. tripartita	P N W I	threetip sagebrush
Atriplex canescens	P N W D	fourwing saltbush
A. confertifolia	P N C I	shadscale
A. nuttallii (*A. gardnerii*)	P N W D	Nuttall saltbush
Berberis repens	P N C D	Oregongrape
Betula occidentalis	P N C I	water birch
B. papyrifera	P N C I	paper birch
Ceanothus sanguineus	P N C D	redstem ceanothus
C. velutinus	P N C I	snowbrush ceanothus
Ceratoides lanata	P N W D	winterfat
Cercocarpus ledifolius	P N C D	curlleaf mountainmahogany
C. montanus	P N C D	birchleaf mountainmahogany
Chimaphila umbellata	P N C I	princes pine pipsissewa
Chrysothamnus nauseosus	P N W I	rubber rabbitbrush
C. viscidiflorus	P N W I	green rabbitbrush

Clematis columbiana	P N C I	rock clematis
C. ligusticifolia	P N W I	white clematis
Cornus stolonifera	P N C D	Redosier dogwood
Crataegus columbiana	P N C I	Columbia hawthorn
C. douglasii	P N C I	black hawthorn
Dryas octopetala	P N C I	white mountain avens
Elaeagnus angustifolia	P I C V	Russian olive
E. commutata	P N C I	silverberry
Eriogonum microthecum	P N C D	slenderbrush eriogonum
Fraxinus pennsylvanica	P N C D	green ash
Holodiscus discolor	P N C I	oceanspray
Juniperus communis	P N X X	common juniper
J. horizontalis	P N X X	creeping juniper
J. osteosperma	P N X X	Utah juniper
J. scopulorum	P N X X	Rocky Mountain juniper
Kochia americana	P N W I	American kochia
Larix lyallii	P N X X	alpine larch
L. occidentalis	P N X X	western larch
Leptodactylon pungens	P N C I	granite gilia
Linnaea borealis	P N C I	twinflower
Lonicera involucrata	P N C I	twinberry honeysuckle
L. utahensis	P N C I	Utah honeysuckle
Oplopanax horridum	P N C I	devilsclub
Pachistima myrsinites	P N C D	myrtle pachistima
Philadelphus lewisii	P N C I	syringa
Phyllodoce empetriformis	P N C I	red mountainheath
P. glanduliflora	P N C I	yellow mountainheath
Physocarpus malvaceus	P N C I	ninebark
Picea glauca	P N X X	white spruce
P. engelmannii	P N X X	Engelmann spruce
Pinus albicaulis	P N X X	whitebark pine
P. contorta	P N X X	lodgepole pine
P. flexilis	P N X X	limber pine
P. monticola	P N X X	western white pine
P. ponderosa	P N X I	ponderosa pine
Populus angustifolia	P N C D	narrowleaf cottonwood
P. deltoides	P N C D	plains cottonwood
P. tremuloides	P N C D	quaking aspen
P. trichocarpa	P N C D	black cottonwood
Potentilla fruticosa	P N C I	shrubby cinquefoil
Prunus americana	P N C D	American plum
P. emarginata	P N C I	bitter cherry
P. pensylvanica	P N C D	pin cherry
P. virginiana	P N C D	chokecherry

Pseudotsuga menziesii	P N X X	Douglas fir
Purshia tridentata	P N C D	bitterbrush
Rhamnus alnifolia	P N C I	alderleaf buckthorn
R. purshiana	P N C D	cascara buckthorn
Rhus glabra	P N C D	smooth sumac
R. radicans	P N C I	poison ivy
R. trilobata	P N C D	skunkbush sumac
Ribes aureum	P N C I	golden currant
R. cereum	P N C I	squaw currant
R. inerme	P N C I	whitestemmed gooseberry
R. viscosissimum	P N C I	sticky currant
Rosa arkansana	P N C I	prairie rose
R. nutkana	P N C I	nootka rose
R. woodsii	P N C I	Woods rose
Rubus idaeus	P N C I	red raspberry
R. leucodermis	P N C I	whitebark raspberry
R. parviflorus	P N C I	thimbleberry
Salix spp.	P N C D	willow
Sambucus coerulea	P N C D	blue elderberry
S. melanocarpa (*S. racemosa*)	P N C D	black elderberry
Sarcobatus vermiculatus	P N C D	greasewood
Shepherdia argentea	P N C I	silver buffaloberry
S. canadensis	P N C I	russet buffaloberry
Sorbus scopulina	P N C I	mountain ash
Spiraea betulifolia	P N C I	white spiraea
S. douglasii	P N C I	pink spiraea
S. splendens (*S. densifolia*)	P N C I	mountain spiraea
Symphoricarpos albus	P N C I	common snowberry
S. occidentalis	P N C I	western snowberry
S. orbiculatus	P N C I	coralberry
S. oreophilus	P N C I	whortleleaf snowberry
Taxus brevifolia	P N C I	Pacific yew
Tetradymia canescens	P N W I	gray horsebrush
Thuja plicata	P N X X	western redcedar
Tsuga heterophylla	P N X X	western hemlock
T. mertensiana	P N X X	mountain hemlock
Ulmus americana	P N C D	American elm
Vaccinium membranaceum	P N C I	thinleaved huckleberry
V. myrtillus	P N C I	myrtle whortleberry
V. scoparium	P N C I	grouse whortleberry
Xanthocephalum sarothrae	P N W I	broom snakeweed
Yucca glauca	P N C I	soapweed