EXPERIMENTAL DESIGN PROTOCOL FOR FOREST VEGETATION MANAGEMENT RESEARCH:
LEVEL B TRIALS — First Approximation —
by
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Province of British Columbia
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EXPERIMENTAL DESIGN PROTOCOL
FOR
FOREST VEGETATION MANAGEMENT RESEARCH:
LEVEL B TRIALS

- First Approximation -

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1 INTRODUCTION

A growing interest in forest vegetation control has created a need for research information on a wide range of vegetation management systems and techniques. To ensure the quality and cost effectiveness of research information, the B.C. Ministry of Forests Research Branch commissioned the development of a guideline for experimentation similar in scope to the Oregon State University CRAFTS\(^1\) program. This report represents one part of a two-level experimental design protocol that defines minimum standards for vegetation management trials. It uses many of the features of the CRAFTS program and data output are expected to be compatible.

The Level A, or "Screening Trial" protocol, provides standards for the least intensive level of experimentation.\(^2\) Screening trials are useful in monitoring short term crop tree response and treatment efficacy of a small number of target vegetation species. Level A methodology may be used to evaluate the potential of a wide array of vegetation management treatments to identify promising candidates for further, more detailed tests. Also, screening trials may be useful for verifying, under local climatic conditions, treatments recommended in the U.S. Pacific Northwest. Details of Level A trials are discussed in a separate protocol.

This report describes the more comprehensive Level B trials. These are intensive studies of new treatments that have a high probability of success based on preliminary screening trial findings. Short- and long-term responses of crop trees and target species are documented as well as shifts in vegetation community composition. Level B trials necessarily involve greater

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investment of time and capital, and should only be used for treatments that have received preliminary testing. Intensive studies may be appropriate for treatments yielding inconsistent screening trial results, or where available efficacy data from outside the province are inadequate.

Both Level A and Level B trials contain common design and assessment conventions, and data from both will be compatible and complementary.

The basic objectives of all forest vegetation management trials are:
  * to identify site and stand treatments that manipulate vegetation on forest sites to favour the establishment and growth of commercial tree species, and to determine further research needs associated with their use;
  * to determine the impact of these treatments on commercial tree species, and on important competing vegetation species or communities.

Trials may be conducted using any of three basic forest vegetation control strategies, all aimed at achieving plantation establishment and early stand development goals. The timing of each, relative to coniferous stand establishment, distinguishes them: the site preparation strategy (prior to crop establishment); the stand establishment strategy (concurrent with stand establishment, i.e. brushing and weeding); and the stand release strategy (following establishment and during juvenile growth and development, i.e. conifer release). In addition, each vegetation control strategy has its own specific set of potential treatments. The list of plant species and plant groups (target vegetation) associated with forest vegetation management problems provides yet a third level of complexity. The number of discrete combinations of control strategy, potential treatments, and target vegetation makes a single experimental approach to vegetation management trials impossible. Therefore, a hierarchy of trial categories was developed where different trials are identified on the basis of common experimental attributes. In some cases, plant growth habit determines the experimental approach. In others, the type of control treatment is the differentiating factor. This protocol outlines experimental procedures for conducting Level B trials for each of the three forest vegetation control strategies defined above.
2 SITE PREPARATION TRIALS

Level B site preparation trials are used to test treatments for managing vegetative competition before the planting operation. Site preparation trials may be used to determine treatment efficacy on herbs, forbs, ferns, grasses, shrubs, or residual trees (hardwood or conifer), which are considered to represent current or potential competition to planned reforestation. Candidate treatments include conventional mechanical brush clearing or prescribed fire approaches which have been used almost exclusively in the province to date. Worthy of investigation, however, are treatments employing forestry herbicides, alone or in combination with conventional methods. These site preparation trials will contribute useful information for ultimately developing effective backlog reforestation systems which optimize prevention as well as control of subsequent vegetative competition.

Research methodologies for investigating site preparation treatments are grouped on the basis of common experimental design and sampling attributes in the sub-sections which follow.

2.1 Low Vegetation Control

Low vegetation control treatments are those applied to sites occupied by annual or perennial herbs, forbs, grasses, ferns, and shrubs, as well as tree species whose mean height is 3 m or less. Low vegetation control treatments are commonly employed on disturbed, N.S.R. forest cover types resulting from harvesting or wildfire. A wide range of treatments is possible, incorporating mechanical, chemical, and prescribed fire, as well as combinations of these methods.

The appropriate sampling technique will vary according to the morphology and growth habit of the target vegetation occupying the site, as well as the type of treatment employed. The approach to sampling must be flexible and appropriate for different combinations of plant species and treatment type.

Experimental Design and Layout

For Level B trials, either completely randomized or randomized complete block experimental designs (described in Appendix 1) may be
used. The choice depends upon uniformity of site physiography and vegetation characteristics and will reflect the investigator's judgement. At least three replications of treatment plots or complete blocks are required in all cases.

Each treatment plot will contain 20 circular subplots arranged in a 4 x 5 grid. For plots assigned a control or herbicide treatment, subplots should be marked with a plot centre stake and tag prior to treatment. For plots assigned a treatment involving site disturbance (i.e. mechanical site preparation or prescribed fire) subplot centre positions should be temporarily marked with flagging tape prior to treatment, and permanently re-marked following disturbance at the time of test planting (treatment plot corner posts act as tie-points for subplot relocation). Iron stakes are especially useful for accurate pre-marking of subplot centres and subsequent relocation following prescribed fire treatment. It is advisable that field layout and baseline assessments be carried out in the year prior to treatment. This is important in the case of foliar herbicide treatments which rely on systemic translocation for maximum effectiveness. Disturbance (bending, crushing, breakage) to target vegetation during plot and subplot layout activities can reduce treatment effectiveness and confound trial results. Lehela and Campbell (1982) recommend delaying subplot layout and baseline assessment until two weeks after glyphosate spray treatments to avoid this problem. They indicate that since it takes approximately two weeks for this herbicide to affect vegetation visibly, assessments made at this time will still be representative of pre-spray conditions. Ultimately, the investigator must decide on the sequence of layout, sampling, and treatment. Where there is doubt regarding treatment confounding, a one-year delay in treatment following layout and subplot baseline sampling is recommended.

Pre-emergent herbicides that are soil active and designed to be applied in the fall or early spring may safely be applied in the fall of the same year as baseline assessment, or in the spring of the following year with no risk of confounding effects due to plant disturbance.
Once randomly assigned, all treatments are carried out prior to test plantation establishment. Season of application may vary according to the optimum timing for each treatment. For instance, pre-emergent herbicides may be applied either in the preceding fall, or early spring of the same year as planting.

During the spring following all site preparation treatments (with the exception of pre-emergent treatments) a test plantation of an appropriate species and stock type must be established within the screening trial boundaries. Test stock must be accurately characterized in terms of seedling morphology and by root-growth testing methods. Normal planting espacement may be employed throughout each treatment plot, although a seedling must also be planted at each of the 20 subplot centre stakes in control or herbicide treated plots. In order to avoid possible stake influence on the seedling, and to facilitate planting and the relocation of the subplot centre should the seedling die, subplot stakes should be removed and relocated 50 cm due north of planted seedlings. In plots subjected to treatments involving site disturbance, the nearest planted seedling to each subplot gridline intersection is selected as the subplot centre and the stake is located as above. Each target vegetation subplot centred on its crop tree seedling provides the data with which to meet trial objectives.

Measures and Records

Level B low vegetation control trials must be assessed on at least four occasions:

- Baseline tree assessment - at the height of vegetative development and prior to treatment, all subplots (permanent and temporary) must be assessed to determine the type, extent, and characteristics of target vegetation. Another baseline assessment is recommended immediately following crop tree planting in order to record initial seedling height and stem diameter.
First reassessment - one growing season after treatment, at the height of vegetative development and after the termination of first-year shoot extension of planted seedlings, all subplots must be reassessed to determine the type, extent, and characteristics of target vegetation, and the morphological characteristics and competitive status of test seedlings.

Second reassessment - as in the first reassessment, after two growing seasons.

Third reassessment - as in the first reassessment, after three growing seasons.

Successive reassessments - at the discretion of the researcher. Data recording conventions are summarized in Appendix 2.

Treatment Response Variables

Subplot data collection focuses on: measured changes in the live canopy coverage of target vegetation species; specific treatment effects (i.e. damage, recovery) on target species; damage to, and growth response of, test seedlings planted following treatment. Treatment response is assessed with subplot, target species, and crop seedling variables.

Subplot vegetation characteristics provide a general description of the vegetation complex occupying the subplot. Non-specific vegetation profile and coverage variables quantify the "total plot" level of vegetation competition as it might affect a crop seedling planted at the subplot centre.

Species-specific target plant morphology and coverage variables subdivide the subplot vegetation complex into its major components. At each subplot, the closest representative specimen of each major target species is located and tagged for this purpose. The height and condition of each specimen is recorded and reassessed annually to provide a measure of treatment effect. While woody plant species are suitable for tagging (or staking), herbaceous species that die back each fall do not permit the permanent identification of a single plant for periodic reassessment. Accordingly, height and condition assessments for herbaceous species must be determined as an average for the species within a subplot.
For vegetation control treatments that disturb the site, tagging of woody plant species is impractical prior to treatment. Tagging should therefore be postponed until plants emerge after such treatments.

Crop seedling variables reflect plant growth and condition and may be useful in assessing treatment tolerance and response.

Response variables and assessment standards are described in Appendix 2.

Proposed Analyses

The completely randomized design will permit a one-way ANOVA based on the mixed-model shown in Table 1 (Appendix 1). Should site conditions require blocking, the randomized complete block design will permit a two-way test using the mixed-model shown in Table 2 (Appendix 1), assuming no block/treatment interaction. Treatment plot means for subplot vegetation height and cover (all species), species-specific height and cover, and test seedling height, diameter, and stem volume may be analysed by either of these models. Problems of missing data must be minimized by ensuring that all major plant species of interest are represented in each subplot, replicate, or block. Minor variations may be acceptable considering the sample size of 20 subplots.

Species-specific data on condition and damage will be suitable for tabular summaries and graphs. Plant and seedling mortality associated with treatments may also be suitable for analysis of variance testing.

2.2 High Vegetation Control

High vegetation control treatments are applied to hardwood or softwood trees (3 m or greater in height) that must be eliminated prior to commercial plantation establishment. The characteristics of these weed species determine method of treatment as well as the appropriate type of trial. Two treatment methods are recognized for high vegetation control: single tree control, and closed canopy species conversion.

Single tree control is most commonly used in conjunction with stand harvesting to eliminate or minimize post-harvesting regeneration of
undesired species. Treatments may be applied either prior to or shortly after harvesting and are usually carried out by hand (basal girdling, herbicide injection, tree felling) since relatively few trees per hectare are involved.

Closed canopy species conversion involves elimination of the entire stand of undesired trees. Its most common application is in the conversion of juvenile hardwood stands to coniferous plantations. Species conversion treatments may also be used to replace diseased, damaged, or repressed conifer stands. Treatments generally involve mechanical clearing or the use of prescribed fire, but herbicide application prior to or following either of these approaches may also be considered. The density and size of target tree species usually dictates which clearing option will be used to prepare the site for plantation establishment.

Experimental procedures appropriate for each method of high vegetation control are described below.

SINGLE TREE CONTROL

The objective of Level B single tree control trials is to eliminate potential competition to planted trees that could result from seeding or suckering. In theory, both forms of reproduction are eliminated once aerial and rooted portions of the parent trees are killed. However, either form of reproduction may still be apparent on research plots as a result of pre-treatment seedfalls, seeding-in from adjacent stands, or 'invading' suckers from elsewhere. To minimize the chances of confounding trials, consideration should be given to the following points:

* Unless seeding-in can be effectively controlled within the experimental area, weed seedling regeneration should not be used as a measure of treatment effect.
* Where root suckering is a target species characteristic, it should only be used as a treatment response variable where plots are large (with large, treated buffers), where site disturbance is minimal (i.e. winter logging), and where no target trees have been felled during harvest.
Trials involving poplar species should ideally be established in undisturbed stands just prior to harvest.

Experimental design and layout

Either of the basic, completely randomized or randomized complete block experimental designs described in Appendix 3 may be used.

Subplot sampling technique

Subplots should be located and sampled at the point of complete foliation (hardwood species) or shoot extension to adequately assess target tree condition and vigour prior to treatment. Refer to Appendix 3 for sampling details. For treatment plots assigned a control or herbicide treatment, subplots should be marked by tagging target trees. For plots assigned a felling treatment, subplot centres may be marked with tagged stakes.

Measures and records

Single tree control trials should be assessed on at least four occasions:

- Baseline tree assessment - at the completion of foliation or shoot extension, depending on species and prior to treatment, all sample trees must be assessed to determine size, condition, vigour, frequency of adventitious sprouting (all species), and frequency of root suckering (suckering species only).
- First reassessment - one growing season after treatment, and at the same period of development as the baseline assessment, all sample trees must be assessed for condition, vigour, and frequency of adventitious sprouting and frequency of root suckering (suckering species only).
- Second reassessment - as in the first reassessment, after two growing seasons.
- Third reassessment - as in the first reassessment, after three growing seasons.
Successive reassessments - at the discretion of the researcher. Data collection and recording conventions are summarized in Appendix 4. The control of more than one target tree species may be assessed in any installation, with only minor modification to plot layout and data recording sheets.

Treatment response variables

Subplot data collection focuses on target tree control and estimated changes in condition or vigour (all species), as well as on the presence and degree of vegetative reproduction (hardwood species only). Treatment response variables are as described in Appendix 4.

Proposed analyses

The completely randomized or randomized complete block design selected for single tree control trials may be analysed using the ANOVAs described in Tables 1 and 2 (Appendix 1). Treatment plot means for target tree survival (or change in vigour classification) and post-treatment vegetative reproduction may be suitable for analysis of variance methods. Covariance analysis may be useful in determining the influence of tree morphology on treatment effect.

CLOSED CANOPY SPECIES CONVERSION

Experimental design and layout

The basic experimental designs recommended for low vegetation control are appropriate for species conversion trials, with the exception of choice of experimental control. It may be impractical to include an untreated control in the experiment if, in the opinion of the investigator, it represents an unrealistic managed stand situation. Rather, alternative treatment effects may be contrasted with a conventional treatment method such as mechanical site clearing. The treatment plot size indicated in Appendix 1 for aerial application methods will likely be the minimum plot size feasible for species conversion trials, since most treatments will include mechanical clearing. The
timing of all treatments and subsequent test plantation establishment is similar to low vegetation control trials.

**Subplot sampling technique**

Subplots should be temporarily located and sampled at the point of full vegetative development of target plants, prior to the application of experimental treatments, using the grid system and the sample intensity described in Appendix 1. Understory herb/shrub species may be sampled using the low vegetation control conventions previously described. Sapling and tree-size specimens of each species should be assessed for their frequency of occurrence and size.

The purpose of this baseline assessment is to characterize treatment plots in terms of target species present, their stocking, density, condition, and vigour. Since all treatments will involve site disturbance, subplot marking is generally not feasible, and baseline sampling may only provide a survey. During the spring, following all treatments, a test plantation of an appropriate species and stock type must be established within the trial boundaries. Test stock must be accurately characterized in terms of seedling morphology and by root-growth testing methods. Normal planting espacement may be employed throughout each treatment plot. When planting is completed, permanent subplot centres can be located using the grid system, sample size, and intensity described in Appendix 1. Allowance for gridline offsets may be necessary to avoid subplot locations on unplantable debris windrows or burned debris accumulations. Each subplot must have at its centre a single planted seedling. The planted seedling closest to each grid intersection point will be selected as the subplot centre, and a labelled subplot stake will be located 50 cm due north of this seedling.

**Measures and records**

The number and type of assessments are the same as for low vegetation control trials (Section 2.1). Data collection and recording conventions are summarized in Appendix 5 for baseline surveys, and in Appendix 2 for post-treatment assessments.
Treatment response variables

Subplot baseline data collection focuses on the stand composition of target tree species, their size and condition, as well as the dominant species of minor vegetation prior to treatment. While representing no measure of response, these data will provide useful site characterization to assist interpretation of treatment effects.

Treatment response variables measured during reassessments include the occurrence and regrowth capacity of trees and minor vegetation after treatment, as well as the survival and growth performance of planted test seedlings. Response variables are as described in Appendix 2.

Proposed analyses

Analytical methods for closed canopy species conversion trials are as described for low vegetation control trials (Section 2.1).
3 STAND ESTABLISHMENT TRIALS

Level 8 stand establishment trials are used to test vegetation control ('brushing and weeding') treatments prescribed from one growing season to several years after planting. Their purpose is to encourage early seedling establishment by minimizing site stresses associated with vegetative competition. This reduces early seedling mortality and improves early growth performance.

Vegetation control for satisfactory stand establishment is not restricted to aerial herbicide application and includes many potentially useful ground applied treatments, either chemical or mechanical. Treatments may be applied after planting to sites occupied by competing vegetation such as herbs, forbs, grasses, ferns, shrubs, and trees. The two factors most critical to treatment success are:

- that the treatment is applied when the seedling can respond promptly and favourably to the temporary reduction of competition;
- that the treatment is selected and applied in a manner that causes the most damage to the target plant or plant group, and the least damage to the developing seedling.

The goal of stand establishment trials for vegetation control is to understand more fully the relationship between treatment and both target plant and crop tree responses.

Experimental Design and Layout

The choice of experimental design is described in Appendix 1. As previously outlined in Section 2.1, pre-treatment vegetation disturbance may confound treatment effect and so plot and subplot layout together with baseline assessment should precede treatment by one year.

Subplot Sampling Technique

Subplots will be permanently located using the grid system and sample intensity described in Appendix 1. Target species will be sampled at the point of full vegetative development and prior to the application of...
experimental treatments. Subplots will contain a single, healthy, planted seedling. To achieve this, the closest healthy seedling to each gridline intersection will be selected, and a labeled subplot stake established 50 cm due north from this seedling. Thus each subplot will be centred on its crop tree seedling.

As previously indicated, the condition of the planted seedling at the time of vegetation treatment largely determines the potential for growth acceleration and the ultimate success of the treatment. In this regard, screening trials of stand establishment treatments should not be carried out in plantations where overall seedling vigour has declined to where release potential is low. The cut-off level must be established prior to experimentation through discussion with field silviculturists. Refining this approximation of critical seedling vigour will require considerable experience in plantation vegetation control, and cannot be directly addressed by this protocol. However, in order to provide future reference information, a test planting of an appropriate, morphologically characterized stock type could be established within treatment plots during the spring following all treatment applications (with the exception of early spring pre-emergent treatments). At this time a single seedling would be planted within each subplot on a plantable spot 50 cm due east from the centre stake. The sampling and recording procedures for data resulting from this additional subplot seedling would be similar to those for site preparation trials for low vegetation control (Section 2.1). An extra crop-seedling data-field may be added to the subplot record to include observations of this additional seedling during the first and subsequent reassessments. Analysis of both data sets would then provide information on the choice of releasing an existing plantation or replacing it with a second planting after treatment.

**Measures and Records**

Stand establishment trials will be assessed on at least five occasions:

- Baseline vegetation assessment – at the height of vegetative development and prior to treatment, all subplots will be assessed
to determine the type, extent, and characteristics of target vegetation. The morphological characteristics and previous height-age field performance of the subplot seedling will also be determined.

- First reassessment - one growing season after treatment (with the exception of preceding fall or early spring, pre-emergent treatments), at the height of vegetative development and not before the termination of subplot seedling shoot extension, all subplots will be reassessed. The type, extent and condition of and damage to target vegetation; and the morphological characteristics, competitive position, and condition of and damage to subplot seedlings will all be determined.
- Second reassessment - as in the first reassessment, after two growing seasons.
- Third reassessment - as in the first reassessment, after three growing seasons.
- Successive reassessments - at the discretion of the researcher.

Data collection and recording conventions for stand establishment treatment trials are described in Appendices 2, 2(a), 2(b), and 2(c).

**Treatment Response Variables**

Subplot data collection focuses on: measured changes in the live canopy coverage of target vegetation species, specific treatment effects on target species, and damage to and growth response of crop seedlings following treatment. Response variables are described in Appendix 2.

**Proposed Analyses**

The proposed analytical techniques are as described for low vegetation control trials in Section 2.1. Additional covariance analyses may be applied to determine the relationship between pre-treatment seedling height growth increments, condition, and growth response following treatment.
4 STAND RELEASE TRIALS

Level B stand release trials are used to test treatments for reducing or eliminating vegetative competition in established stands. Release treatments are most commonly applied to planted stands greater than five years of age, or to established natural regeneration in the sapling stage. The principal target vegetation is most often a relatively homogeneous hardwood tree cover that has a growth habit capable of dominating and repressing crop tree growth over long periods of stand development. The stand release strategy is considered an intensive silviculture practice and its main purpose is to maintain or improve crop growth. Potentially useful treatments include: aerial herbicide (foliar or soil active) sprays; distribution of soil-active pellets; ground-level basal stem treatments (e.g. herbicide oil sprays, herbicide injection, basal frilling with herbicide); and stem girdling and tree felling with or without cut-stump herbicide treatments.

The focus of Level B stand release trials is on assessing treatments in terms of crop tree response and efficacy in controlling target vegetation. Data collection methods for crop tree assessments resemble those for site preparation and stand establishment trials. Methods for assessing target vegetation control are similar to those described for single tree control trials.

In experimental design, sampling, and analytical approaches for screening trials, the following factors will be noted:

- variation in crop trees (size, vigour, condition) is expected to be large.
- variation in crop tree competitive stress will be large.
- crop tree response to treatment will likely be affected by the degree of repression prior to treatment.
- most measurement variables associated with crop tree growth will require sensitive and accurate measurement techniques and lengthy assessment periods before meaningful trends in treatment effects are detectable.
Accordingly, we suggest the sample size for stand release trials be larger than for previously described vegetation control trials, and recommend destructive crop tree sampling techniques to accurately assess treatment effect at the end of the experiment.

Screening trials of all potential stand release treatments may be undertaken using the same experimental approach.

**Experimental Design and Layout**

Either of the basic, completely randomized or randomized complete block designs described in Appendix 1 may be used. Due to the sample size requirements of stand release trials, the minimum treatment plot size may only be determined by the distribution of the crop trees, regardless of the method of application. Treatment plots must include a treated buffer around subplots of at least one crop-tree height in width.

**Subplot Sampling Technique**

Sampling subplots must be located and sampled at the point of full vegetative development of target plants, and prior to the application of experimental treatments. Each treatment plot must contain a minimum of 30 subplots of 50 m$^2$ ($r = 3.99$ m) located by a random start, systematic grid system. The closest healthy crop tree of a predetermined species to each gridline intersection will identify the subplot centres. If crop-tree variation is excessive, sample size must be increased. Subplot marking follows procedures described in Appendix 1, with tags attached to crop trees at breast-height. Where this is impractical, centre stakes adjacent to crop trees may be marked. Subplots should be well-marked with paint or ribbon for easy relocation.

The closest representative specimen for each target tree species of interest is selected at each subplot, and marked with paint or ribbon and a tag indicating subplot number and tree species name. In some cases the sample target tree may lie outside the 50 m$^2$ subplot, and a compass bearing and distance to sample should be recorded on the subplot data sheets. Selected tree species must be well-represented on the site to enable a specimen of each to be sampled at each subplot.
Measures and Records

Stand release trials should be assessed on at least four occasions:

· Baseline assessment - at the period of full crown foliation of target trees, and prior to treatment, all subplots must be assessed to determine crop tree and target tree morphological characteristics and inter-tree competitive status.

· First reassessment - one growing season after treatment, at the height of vegetative development, all subplots must be assessed to determine both efficacy of treatments on target tree species and the incidence and type of any adverse effects on crop trees.

· Second reassessment - a second treatment efficacy assessment of target trees is recommended, and may be completed during the second growing season after treatment.

· Third reassessment - during the fifth growing season after treatment an assessment of crop tree morphology should be completed. At this time, crop trees are remeasured, and a record made of any changes in tree vigour and injury status. On the basis of this fifth-year assessment, the researcher may determine whether destructive crop tree analysis is warranted, or whether a postponement is justified.

The data recording format for stand release screening trials is presented in Appendix 6.

Treatment Response Variables

Subplot data collection focuses on measured or estimated changes in target tree vigour, injury, and regrowth response, as well as on crop tree encroachment, vigour, injury, and tree growth response. Response variables are as described in Appendix 6.

Proposed Analyses

The mixed model ANOVAs described in Tables 1 and 2 (Appendix 1) may be used to analyse crop tree growth response from remeasurement or destructive sample data. Due to the covariate relationship between pre-
and post-treatment tree growth, analysis of covariance techniques may be employed where the necessary assumptions can be met. Alternative methods of analysis include stratification of crop trees on the basis of pre-treatment competitive stress or tree vigour, with separate analyses within strata.

Species-specific data on target tree responses to treatment may be suitable for tabular summaries and graphs.
SUMMARY

The preceding guidelines are designed to separate vegetation management trials into distinct experimental categories. The criteria used to differentiate categories directly affects experimental methodology and, therefore, will be of use in selecting Level B procedures appropriate for testing most treatments in most vegetation communities. While the distinction between trials is clear within this guideline, there may, nevertheless, be site conditions or research objectives that span one or more categories. In these situations, the investigator must customize the experimental procedures to reflect these special situations. In addition, researchers may wish to test treatments in a factorial experiment. This may be done simply by modifying the procedures for analysis. In all cases, however, the methods and assessment procedures should remain consistent with Level B trial guidelines.

As suggested in the Introduction (Section 1), one of the basic objectives of provincial trials is to determine the effects of treatments on all important vegetation species and plant complexes. Vegetation management trials must be carried out within an ecological framework, requiring detailed site and stand description. It is strongly recommended, therefore, that a full ecosystem description be made of all installations so that resulting data may be fully shared within the program.

It is essential that all details of target plant and crop tree phenology be observed and recorded at the time of vegetation control treatment application. This is particularly true of foliar herbicides since the physiological condition of the target plant at the time of application can strongly influence treatment efficacy. A complete log of all treatment logistics, time studies, and costs should be kept by the investigator for research planning purposes as well as for potential use by others in operational-scale vegetation management programs. The "CRAFTS Experimental Design Manual"\(^3\) (Walstad and Wagner, 1982) contains the format for such information, and should be used as a checklist during trial planning and operations. This format is reproduced in Appendix 7.

\(^3\) Ibid.
6 REFERENCES


APPENDIX 1

Basic Experimental Design, Layout, and Analysis for Level B
Forest Vegetation Management Trials

1. Experimental Design

Each screening trial should test a minimum of three (and preferably more) vegetation management treatments. One of these treatments must be a control (untreated site condition); the remaining treatments may be any chemical or non-chemical control method considered potentially useful on the site or vegetation community under study. It is desirable to have at least one non-chemical treatment in each screening trial.

An installation (trial) must have a minimum of three replications. Experimental design should be selected on the basis of site homogeneity. For sites considered to be homogeneous in physiography and vegetation characteristics, the completely randomized design is recommended. Where minor variations in site exist, grouping in homogeneous blocks is suggested to reduce the experimental error, and the randomized complete block design should be adopted.

2. Treatment Plot Layout

Treatment plot dimensions will vary according to method of treatment application, particularly for herbicide sprays. As shown in Figure 1, aerial herbicide applications (helicopter-mounted boom and nozzle sprayers), require a minimum of 2.0 ha for treatment plots. Ground applications (Solo backpack sprayers) require a minimum of 0.20 ha plots.

Treatment plot corners should be marked with 2 m tall, 10 cm x 10 cm orange-painted posts. The outside faces of the corner posts should be labelled with metal tags bearing the appropriate replicate or block and plot numbers.
FIGURE 1. Minimum recommended plot size for aerial and ground applications, herbicide-free buffer and subplot location specifications for Level B vegetation management trials.
3. Subplot Layout and Intensity

Each treatment plot must contain a minimum of 20 circular subplots which are the sampling units for treatment responses. Subplots may range from 5 to 20 m$^2$ in area (radius equals 1.26 to 2.52 m) depending on the size of the target vegetation species. For sites with large target species or wide species diversity, larger subplots should be used. Subplot locations will be determined systematically from a random start. The location of the first subplot in each treatment plot may be selected by a random toss of a stick from point A, as shown in Figure 1. Each subplot centre should be marked with a 1.5 m tall stake bearing metal labels that identify the replicate or block, treatment, and subplot number (i.e. 1-2-13 for block 1, treatment 2, subplot 13). Subplot centres must always be crop-tree centred for freshly planted trees. In the case of existing crop trees, the subplot centre is offset from the grid intersection point to the nearest healthy seedling.

4. Proposed Analysis

Tables 1 and 2 illustrate the appropriate F-test for the analysis of variance of trial data, depending on the experimental design employed. An important assumption in the analyses is that the dependent variables being measured are randomly distributed. Where this assumption cannot be met it is recommended that treatment plot means be used in the ANOVAs, thus eliminating sampling error from Tables 1 and 2.
TABLE 1. ANOVA table for Level B vegetation management trials based on a completely randomized, single factor design (mixed model with three treatments, three replications)

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Factor Type</th>
<th>Level</th>
<th>d.f.</th>
<th>Expected F-Test (d.f.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatments</td>
<td>fixed</td>
<td>3</td>
<td>2</td>
<td>MS treatment</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>MS replicates</td>
</tr>
<tr>
<td>Replicates</td>
<td>random, nested</td>
<td>3</td>
<td>6</td>
<td>MS treatment</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>MS replicates</td>
</tr>
<tr>
<td>Sampling Error</td>
<td>random, nested</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>171</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>179</td>
</tr>
</tbody>
</table>

TABLE 2. ANOVA table for Level B vegetation management trials based on a randomized complete block, two factor design (mixed model with three treatments, three replications)

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Factor Type</th>
<th>Levels</th>
<th>d.f.</th>
<th>Expected F-Test (d.f.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blocks</td>
<td>random</td>
<td>3</td>
<td>2</td>
<td>MS blocks</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>MS error</td>
</tr>
<tr>
<td>Treatments</td>
<td>fixed</td>
<td>3</td>
<td>2</td>
<td>MS treatment</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>MS experimental error</td>
</tr>
<tr>
<td>Experimental</td>
<td>mixed, crossed</td>
<td>4</td>
<td></td>
<td>MS experimental error</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>MS sampling error</td>
</tr>
<tr>
<td>Sampling Error</td>
<td>random, nested</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>171</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>179</td>
</tr>
</tbody>
</table>
APPENDIX 2

Measures and Records for Vegetation Management
Trials on Herbs, Forbs, Grasses, and Shrubs

1. Measurement Variables

a) Target Vegetation

Target species of interest should be predetermined for each Level 8 installation. Only species that predominate the site under study; that are known to present a vegetation problem; or that are suspected of becoming a problem following treatment should be monitored. While no limit should be placed on the number of species being investigated, practical limits in monitoring effort should be observed. Normally, between three to five major species should be selected for study. These species must be well-represented throughout the site in order to avoid problems of missing data. Subplot assessment variables for major vegetation species are described in each of the subsections (i) through (vi) below.

Vegetation control treatments often result in shifts in vegetation composition. Species that are poorly represented prior to treatment may become major competing species following treatment. In some cases, species absent before treatment invade and occupy the site after treatment. In most situations it is difficult to predict species shifts. Level 8 assessment procedures should therefore permit detection of this phenomenon. Subsection (vii) describes an optional subplot inventory of additional plant species. Using this approach, the presence and abundance of any additional species of interest may be recorded for each subplot. The effort required to collect the additional information is minimal, since no permanent tagging or measurement is involved. Any number of species may be added or removed during successive assessments.
(i) **Subplot Vegetation Profile** - describes the competitive structure of the major species complex occupying the subplot. It should estimate the modal height of the complex (nearest 0.1 m) and does not require direct measurement of all individuals.

(ii) **Subplot Vegetation Cover** - percent cover (nearest five percent) of the subplot for all (major and minor) species present in the subplot. The quadrant method of estimating plant canopy coverage should be used (see Appendix 2(a)).

(iii) **Specimen Height** - the height of the living portion (measured to nearest centimetre) of each major target specimen for each subplot. Herbaceous species height is the average for the species within the subplot (estimated to nearest 0.1 m).

(iv) **Species-Specific Vegetation Cover** - the percent cover (estimated to nearest five percent) of each major target species (all specimens) within the subplot (see Appendix 2(a)).

(v) **Specimen Plant Vigour** - see Appendix 2(d).

(vi) **Species-Specific Condition/Damage Status** - the condition and damage status of each of the major target specimens measured in (iii) (see Appendix 2(b)).

(vii) **Species-Specific Control Rating** - the estimated level of vegetation control of the plant specimen due to treatment, as evidenced by degree of top kill, defoliation, abnormal growth form, or mortality. The rating is visual, subjective, and expressed as a percentage. Conversion of the control rating to the efficacy scale of the Expert Committee on Weeds (E.C.W.) Research Abstracts (1983) is intended (see Appendix 2(b)).
(viii) **Optional Species Inventory** - provides a list of minor species within the subplot. The presence of a species of interest is noted by its name and an estimate of abundance. Abundance is a highly subjective variable, depending on the structure and size of the plant. A simple, three-point rating is recommended as follows:

<table>
<thead>
<tr>
<th>Code</th>
<th>Abundance level</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>trace (at least one plant in subplot)</td>
</tr>
<tr>
<td>2</td>
<td>common</td>
</tr>
<tr>
<td>3</td>
<td>abundant</td>
</tr>
</tbody>
</table>

b) Crop Seedling

(i) **Seedling Height** - the current total height (nearest centimetre) of the test seedling at subplot centre.

(ii) **Stem Diameter** - measured at 1 cm above ground level, to nearest 0.01 cm (o.b.).

(iii) **Seedling Vigour** - see Appendix 2(d).

(iv) **Degree of Overtopping** - the degree of overtopping by competing vegetation (see Appendix 2(c)).

(v) **Condition/Damage Status** - the condition and damage status of the crop seedling (see Appendix 2(b)).

(vi) **Crop Seedling Tolerance Rating** - the estimated level of tolerance of the crop seedling to treatment, as evidenced by presence and severity of damage symptoms. Conversion of this rating to the E.C.W. crop tolerance scale is intended (see Appendix 2(b)).
2. Recording Convention

All field notes and subplot measurements should be recorded directly onto 80-column coding forms, the format of which is illustrated in Figure 2. Additional details of coding-form use are as follows:

(i) **Header File** (Module Name and Description) - to facilitate provincial data sharing and retrieval, the Research Branch will assign an appropriate module name (E.P. number) to cover all provincial screening trials. Sub-E.P. numbers, provided by research co-operators, will identify specific screening trials. The co-operators will also provide appropriate data module descriptions. For details on header files, consult the Research Branch "Librarian" data set naming conventions.\(^4\)

(ii) **Assessment Number** - identifies the type of assessment represented by the data.

   1 - Baseline vegetation assessment  
   2 - First reassessment  
   3 - Second reassessment  
   4 - etc.

(iii) **Replicate or Block Number** - determined by randomization scheme and the choice of experimental design.

(iv) **Treatment Number** - a number code identifying the treatment; all code definitions must be recorded on multiple card layout form.

(v) **Subplot Number** - according to subplot layout and permanent identity tags.

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Assessment #
(1) - Identifies the type of assessment.

Subplot Identity
(2) - Treatment #
(3) - Subplot #

Subplot Vegetation Description
(1) - Subplot Vegetation Profile
(2) - Subplot Vegetation Cover

Crop Seedling Specimen Description
Species  (1) - Name Code

Morphology  (1) - Seedling Height
(2) - Seedling Diameter
(3) - Seedling Vigour
(4) - Degree of Overtopping

Condition/Damage  (1) - Foliage Condition
(2) - Leader Shoot Condition
(3) - Stem Condition
(4) - Damage Cause
(5) - Crop Seedling Tolerance Rating

Height Increment
(1) - Current Year - 1 Increment
(2) - Current Year - 2 Increments
(3) - Current Year - 3 Increments
(4) - Current Year - 4 Increments

Target Plant Specimen Description
Species  (1) - Name Code
(2) - Specimen Location - Azimuth Bearing
(3) - Specimen Location - Distance

Morphology  (1) - Specimen Height
(2) - Subplot Cover by Species
(3) - Specimen Vigour

Condition/Damage  (1) - Foliage Condition
(2) - Stem Condition
(3) - Damage Cause
(4) - Control Rating

Species Inventory (Optional)
(1) - Species Name
(2) - Plant Abundance

FIGURE 2. Illustration of the field coding form layout for recording subplot data in herb, forb, grass, and shrub control trials.
Only one data field is illustrated for crop tree, target plant, and other species. Repetition of these fields on successive coding lines will permit the assessment of any number of additional specimens in subplots depending on plant community complexity and trial objectives.
(vi) **Crop Seedling/Target Vegetation Names** - the species code convention should be that of the Provincial Ecosystem Classification Program. The general rules require a seven-letter code made up of the first four letters of the plant genus, followed by the first three letters of the plant species. For more information, consult "Rules Used in Preparing the Ministry of Forests Vegetation Coding List".5

(vii) **Crop Seedling Previous Increments (Optional)** - the first two-column field is used to record the first-year height growth increment at the time of first reassessment in site preparation trials where an initial measurement at planting was not completed; thereafter, these columns may be eliminated from the crop seedling data field if reassessments are carried out at annual intervals. The field may also be used during the baseline vegetation assessment in establishment treatment trials to record previous height-age relationships for older, established seedings. Only height-growth after planting is measured in this manner, and only to a maximum of four years back-dating.

(viii) **Target Specimen Location** - for easy relocation of target vegetation specimens, the azimuth bearing and approximate distance (nearest 1 m) to each specimen may be recorded in the appropriate data fields.

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APPENDIX 2(a)

Estimating Percent Plant Cover Within Subplots\textsuperscript{6} (Walstad and Wagner, 1982)

Plant canopy cover is defined as the vertical projection of the crown or canopy of a species to the ground surface, expressed as a percentage of the subplot area. Plant cover estimates should be made to the nearest five percent on all subplot quadrants. Each circular subplot may be divided into quadrants and cover estimates may be made for each quadrant by the observer standing at the subplot centre. The point where subplot circumference and subplot radii intersect should be permanently marked to aid the visualizing of the quadrant area. Alternatively, flexible, circular plot hoops may be used for small area subplots. The cover value for each subplot is the sum of values for all four quadrants.

There are two fundamental approaches to estimating plant canopy coverage in a fixed subplot area. When the cover for a particular species is greater than 25 percent of the subplot area, it is fairly easy to estimate the amount of coverage relative to the total area of the subplot. However, when the cover is less than 25 percent, or the cover is distributed in small clumps over the entire subplot, it becomes more difficult to accurately assess. In this situation the area-addition method can aid the recorder in making accurate estimates. With this system, the observer estimates the actual area covered by each clump (in square metres) within each quadrant of the subplot, sums all the areas for each species, and converts the sum to a percentage of the total subplot area.

The approximate relationship between area and percent cover calculated for 10 m\textsuperscript{2} subplots is given below:

\textsuperscript{6} Ibid.
<table>
<thead>
<tr>
<th>Canopy coverage (%)</th>
<th>Equivalent area (m²)</th>
<th>Approximate area dimensions (cm x cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>0.5</td>
<td>71 x 71</td>
</tr>
<tr>
<td>10</td>
<td>1.0</td>
<td>100 x 100</td>
</tr>
<tr>
<td>15</td>
<td>1.5</td>
<td>122 x 122</td>
</tr>
<tr>
<td>20</td>
<td>2.0</td>
<td>141 x 141</td>
</tr>
<tr>
<td>25</td>
<td>2.5</td>
<td>158 x 158</td>
</tr>
</tbody>
</table>

If observations are made carefully and thoughtfully, ocular estimates should be accurate enough that meaningful changes in plant community composition over time can be detected. It is best if all observations on a given set of sublots are made by the same observer or team of observers. By making independent coverage estimates and then comparing them, investigators can assist each other in honing their observation skills and increasing accuracy.

1. Subplot Vegetation Cover

Cover estimates for all target plant species are made from an aerial or "bird's-eye" view. Canopy overlaps between different plants or species are not counted, and therefore the cover estimates for plant canopies and that for bare ground or slash should total 100 percent of the area for each quadrant.

2. Species-Specific Plant Cover

Cover estimates of each target plant species of interest are made in each subplot. Because the canopy overlap between different species should be counted, when the cover values in each quadrant for each species are totalled, they may exceed 100 percent.
APPENDIX 2(b)

Specimen Condition/Damage Codes for
Vegetation Management Trials7 (Walstad and Wagner, 1982)

1. Target Vegetation Species
   A six-column field is used to record the condition/damage of target
vegetation species, and permits up to two codes to be recorded for each
observation. Single codes are adjusted left in the field. Where two codes
per observation are warranted, the dominant of the two is entered first. The
first two columns specify foliage condition; the second two, stem condition;
and the next two columns specify the cause of any observed damage. An
additional three-column field specifies the percentage control rating. The
observation codes for these variables are as follows:

**Foliage Condition Code**
- H - No visible effect (healthy)
- E - Enlarged leaves
- D - Deformed leaves
- R - Reduced leaf size
- Y - Chlorotic leaves (yellow)
- M - Mottled leaves
- N - Necrotic leaves
- A - Leaves absent, defoliated
- B - Browsed
- O - Other symptoms (specify)

**Stem Condition Code**
- H - No visible effect (healthy)
- I - Shortened internodes
- C - Cut, clipped or broken
- B - Browsed
- S - Smashed, crushed or trampled
- P - Partial topkill, vigorous stem sprouting
- W - Partial topkill, weak stem sprouting

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7 Ibid.
V - Complete topkill, vigourous basal sprouting
T - Complete topkill, weak basal sprouting
D - No visible living parts (dead)
M - Plant missing
O - Other symptoms (specify)

Damage Cause Code
A - None
H - Herbicide
M - Mechanical equipment
T - Hand tools
S - Falling slash (human caused)
X - Falling or sliding debris
E - Climate - frost
N - Snow press
V - Vegetation press
W - Climate - drought
R - Rodents, small animals
B - Big game
L - Livestock
F - Fire
I - Insects
D - Disease
O - Other (specify)
U - Unknown

Control Rating
- A 0-100 percent rating scale is used to assess the level of control over target plants achieved through treatment. This scale should reflect a linear progression between no control and complete control, assessed on the basis of the degree of topkill achieved. The rating convention assigns zero percent where there is no visible treatment effect (i.e. a completely healthy plant), and 100
percent where the plant is killed. Before a 100 percent rating may
be assigned to woody plants, however, evidence of root collar
cambium death must be observed with the use of a knife-cut
technique. This rating convention will permit subsequent
conversion to the scale used in E.C.W. (1983) silviculture
abstracts.

2. Crop Seedling

An eight-column field is used to record the condition/damage of test
seedlings, and permits up to two codes to be recorded for each observation.
The first two columns specify foliage condition; the second two, leader shoot
condition; the next two, stem condition; and the final two columns specify the
cause of any observed damage. An additional three columns specify the crop
seedling tolerance to treatment. The observation codes for these variables
are as follows:

**Foliage Condition Code**

- **H** - No visible effect (healthy)
- **Y** - Chlorotic (yellow)
- **M** - Mottled
- **N** - Necrotic
- **A** - Needles absent, defoliated
- **B** - Browsed
- **D** - Dead buds on lateral branches
- **O** - Other symptoms (specify)

**Leader Shoot Condition Code**

- **H** - No visible effect (healthy)
- **C** - Curled
- **F** - Forked
- **B** - Browsed
- **T** - Dead terminal bud
- **S** - Snapped, broken
- **A** - Absent, missing
- **O** - Other symptoms (specify)
**Stem Condition Code**

H - No visible effect (healthy)
P - Bark peeled or abraded
B - Stem bent
S - Stem smashed, crushed, trampled
C - Stem cut, clipped, broken
D - Tree dead, dying
M - Tree missing
O - Other symptoms (specify)

**Damage Cause Code**

A - None
H - Herbicide
M - Mechanial equipment
T - Hand tools
S - Falling slash (human caused)
X - Falling or sliding debris
E - Climate - frost
N - Snow press
V - Vegetation press
W - Climate - drought
R - Rodents, small animals
B - Big game
L - Livestock
F - Fire
I - Insects
D - Disease
O - Other (specify)
U - Unknown

**Crop Seedling Tolerance**

A 0-100 percent rating scale is used to assess the degree of crop seedling tolerance to treatment. This scale should reflect a linear progression between complete crop seedling tolerance and no tolerance, assessed on the basis of degree of topkill. The rating convention follows that previously described for target vegetation. Conversion of this rating to E.C.W. (1983) convention is intended.
APPENDIX 2(c)

Estimates of Degree of Overtopping for Crop Seedlings in Vegetation Management Trials

Degree of overtopping by competing vegetation is a subjective assessment of crop tree competitive stress. It is based on a judgement of the anticipated height-growth trajectory of the crop tree relative to the surrounding vegetation species. Three relative levels of overtopping exist as follows:

Code 2: Overtopped - the leader of the crop tree is at present overtopped by surrounding vegetation; crop tree available sunlight is greatly reduced.

Code 1: Threatened - the leader of the crop tree is at or near the same height of the surrounding vegetation, but is likely to be overtopped within two growing seasons.

Code 0: Free-To-Grow - the leader of the crop tree is well-above the surrounding vegetation and is not likely to become threatened.
APPENDIX 2(d)

Estimates of Crop Seedling and Target Plant Vigour in Vegetation Management Trials

The assessment of crop seedling vigour is a highly subjective estimate. Assessment criteria include foliage colour, needle number, needle length, shoot elongation, and stem calipre. A five-class code is proposed as follows:

0 - dead (must be confirmed by knife-cut).
1 - moribund, near death, little or no visible shoot growth.
2 - poor vigour, minimal shoot growth, small needle complement, etiolated shoot development, tendency for poor form due to inadequately rigid stem.
3 - moderate vigour, overall growth rate and condition lower than for open-grown seedlings.
4 - good vigour, growth rate and quality similar to open-grown seedlings.

Refinement or revision of this morphologically-based assessment code may be possible as experience accumulates in vegetation management studies.

Assessment of target plant vigour uses the same five-class code. Criteria for assessment may be based on the foliage complement of woody plant species, the growth rate and plant size achieved by annual and perennial species, and the overall dominance exhibited by the plant in the subplot. The target plant vigour description is designed to augment cover, condition, damage, and control ratings to more clearly interpret treatment responses.
1. Experimental Design

Each trial should test a minimum of three single tree control treatments. One of these must be a control (untreated trees); the remaining treatments may be any of chemical type, chemical rate, application date, or non-chemical methods considered to have potential for the tree species or species group under study.

An installation (trial) must have a minimum of three replications. Experimental design should be selected on the basis of site homogeneity. For sites considered to be homogeneous in physiography and target tree characteristics, the completely randomized design is recommended. Where minor variations in site exist, grouping in homogeneous blocks is suggested to reduce experimental error, and the randomized complete block design should be adopted.

2. Treatment Plot Layout

Treatment plot dimensions should vary according to the species of target tree and whether it reproduces by root suckering. Plot dimensions should also vary, depending on target tree distribution and estimated root elongation.

a) Coniferous and Non-Suckering Hardwood Target Trees
   Treatment plots must be large enough to incorporate 20 specimen target trees of the species under study. Plots should be squared off and permanently marked as described in Appendix 1.

b) Hardwood Trees Capable of Root Suckering
   Treatment plots must be large enough to incorporate an inner group of 10 (minimum) specimen target trees of the species under study. In addition, they must incorporate an outer, treated buffer
area (beyond the squared-off inner plot) of one average tree length in width, within which all trees will receive the prescribed treatment.

3. Subplot Layout and Intensity

a) Coniferous and Non-Suckering Hardwood Target Trees
   Sampling subplots consist of a single, centralized tree specimen. Subplot trees should be labelled in the manner described in Appendix 1, with permanent tags affixed to the treated stem at breast height and oriented in a convenient manner. A paint marking will also improve relocation chance. Subplot centre stakes are required where treatments involve tree felling.

b) Hardwood Target Trees Capable of Root Suckering
   Sampling subplots consist of four, 12 m transects radiating in cardinal directions from each specimen in the plot. A cluster of four assessment plots are distributed along each transect at the 3, 6, 9, and 12 m points. Each assessment plot is 4 m² in area (r = 1.13 m). A permanent stake should be established at the 12 m point of each transect to facilitate relocation of assessment plots. Assessment plots should be sequentially numbered in a logical manner to permit accurate reassessments. Alternatively, where treatment plots are large, a systematic grid (with random start) of circular, 20 m² subplots may be used. Grid dimensions should be chosen to adequately represent the treatment plot. Sample size should be no less than 20 subplots.
APPENDIX 4

Measures and Records for Trials of
Single Tree Control Treatments

1. Measurement Variables for Target Specimens

   a) **Tree Height** - (metres) is estimated to the nearest five percent.

   b) **Tree Diameter** (d.b.h.o.b.) - is measured to the nearest 0.1 cm.

   c) **Tree Vigour** - tree vigour describes the rate of growth and overall health of the tree as expressed by the crown. Vigour codes are listed in Appendix 4(a).

   d) **Tree Condition/Damage** - tree condition describes the basic pathological condition of the main stem. Condition codes are listed in Appendix 4(a).

   e) **Vegetative Reproduction** - the presence and number of adventitious shoots on the main stem or root collar region (all hardwood species), or of root suckers within assessment plots (suckering hardwoods only), must be determined at the baseline and subsequent reassessments. Shoots (living and dead) present at the baseline assessment should be tallied to record the shoot production and mortality resulting after treatment. Recording details are described in the section, "Recording Convention", below. Target tree height and diameter need not be repeated at each reassessment, whereas condition, vigour, adventitious stem growth, and root suckering are re-evaluated at each reassessment.

   f) **Control Rating** - the estimated level of control of the target tree due to treatment, as shown by degree of topkill, defoliation, and rate of vegetative re-growth. The rating is visual, highly subjective, and
expressed as a percentage. Percent control estimates must integrate parent tree control (defoliation) with degree of resprouting or suckering for a meaningful treatment rating to be achieved. Conversion of the rating to the E.C.W. scale is intended.

2. Recording Convention

Figure 3 illustrates the data coding format for single tree control trials utilizing the radiating, transect sampling method.
### Target Tree Specimen Description

**Species**  
(1) - Name Code

**Morphology**  
(1) - Tree Height  
(2) - Tree Diameter  
(3) - Tree Vigour

**Condition/Damage**  
(1) - Crown Condition  
(2) - Stem Condition  
(3) - Damage Cause  
(4) - Control Rating

**Adventitious Shoots**  
(1) - Living Adventitious Shoots  
(2) - Dead Adventitious Shoots

### Root Sucker Assessment Plots (Optional, for appropriate species only)

**Plot 1**  
(1) - Living Root Sucker Shoots  
(2) - Dead Root Sucker Shoots

(continued for 16 plots)

---

**FIGURE 3. Illustration of the field coding form layout for recording subplot data in single tree control trials.**  
The format of assessment plot data fields for use with suckering species must be repeated for 16 plots.
APPENDIX 4(a)

Target Tree Condition, Damage, and Vigour Codes for
Trials of Single Tree Control Treatments

1. Tree Condition

A seven-column field is used to record the condition of residual target
trees. The first three columns specify crown condition; the next two specify
stem condition; and the last two columns specify the cause of any observed
damage. Where only one stem condition and damage code is warranted, only one
of each of the two columns is used, with the entry adjusted to the left.
Where two codes per observation are warranted, the dominant of the two is
entered first. The observation code is as follows:

Crown Condition Code
- A 0-100 percent estimate of foliation of the crown is recorded for
each subplot tree at each assessment. Estimates of the degree of
leaf coverage of the crown following treatment should be based on
that made at the baseline assessment. Accuracy of estimates may be
improved by photographing the crown at each assessment, and comparing
with baseline crown condition. All estimates and photographs should
be made at the completion of leaf development during the active
growing season.

Stem Condition Code
0- Healthy stem
1- Presence of a decay fungus sporophore
2- Presence of a blind conk
3- Presence of a dead or broken top
4- Present of a crack
5- Presence of a scar
6- Vigourous basal sprouting
7- Weak basal sprouting
8- Severed stem
9- Other (specify)
Damage Cause Code

0 - No Damage
1 - Frost damage
2 - Pre-harvesting damage
3 - Harvesting damage
4 - Herbicide damage
5 - Mechanical treatment injury (including felling)
6 - Other (specify)

2. Tree Vigour

a) Hardwood Target Trees

Assessment of tree vigour for hardwoods uses a four-class code adopted from Hough and Taylor (1946).

0 - dead.

1 - poor vigour; flattened, spindly or dying tops, scanty foliage of poor colour, and very slow growth.

2 - medium vigour; less than full crown, slower growth than normal due to having occupied a lower crown position in the uncut stand.

3 - good vigour; full crown and dense foliage of good colour, with rapid growth.

b) Coniferous Target Trees

The tree vigour classification for ponderosa pine by Miller and Keen (1960) is sufficiently versatile to apply to most coniferous target trees. It consists of a four-class system, based on crown vigour and stratified by relative age of the tree.
The vigour code consists of the following five classes:

0 - dead.

1 - poor vigour.

2 - fair vigour.

3 - medium vigour.

4 - good vigour.

Consult the source for additional details of the vigour classification.
APPENDIX 5

Measures and Records for Trials of
Closed Canopy Species Conversion Treatments

1. Measurement Variables - Baseline Survey

   a) Target Tree Species
      
      Two or three major target tree species may be assessed in
      subplots prior to treatment. The closest representative specimen to
      each subplot centre is selected for height, diameter, condition, and
      vigour assessment, based on the measurement precision and observation
      codes described in Appendix 4.

   b) Minor Vegetation Species
      
      Up to three minor vegetation species may be assessed in subplots
      prior to treatment. The closest representative specimen of each
      species to each subplot centre is selected for morphological
      assessment. The subplot cover for each species is estimated with the
      use of the observation methods and codes described in Appendix 2.

2. Measurement Variables - Reassessments

   Following treatments and the planting of test seedlings, assessments and
   reassessments follow the procedures and formats described in Appendix 2.

3. Recording Convention - Baseline Survey

   The data recording format used in the pre-treatment baseline survey
   follows the data fields illustrated in Figures 2 and 3, depending on the
   structure of the stand and objectives of the survey.

4. Recording Convention - Reassessments

   The data recording format and conventions used for post-treatment
   assessment are the same as previously described for low vegetation control
screening trials. Procedures summarized in Appendix 2, 2(a), 2(b), and 2(c) may be directly applied. In post-treatment assessments target vegetation species may be represented either by tree species (from seed or vegetative reproduction) or herb, forb, grass, or shrub vegetation species.
APPENDIX 6

Measures and Records for
Stand Release Trials

1. Measurement Variables

a) Crop Trees

(i) **Frequency** - tallied by species within the subplot.

(ii) **Height** - (metres) measured or estimated to the nearest five percent (preferably by height pole).

(iii) **Diameter** (d.b.h.o.b.) - measured to the nearest 0.1 cm.

(iv) **Height of Live Crown** - (metres) measured to the nearest five percent.

(v) **Tree Vigour** - see Appendix 6(c).

(vi) **Crown Position** - the crown position of the crop tree (see Appendix 6(a)).

(vii) **Degree of Encroachment** - the degree of target tree encroachment on crop tree growing space (see Appendix 6(b)).

(viii) **Condition/Damage** - the observation code for condition/damage is as described for planted trees in Appendix 2(b).

(ix) **Crop Tolerance** - the crop tolerance rating is as described for planted trees in Appendix 2(b).
a) Target Tree Species

(i) **Frequency** - tallied, by species, within the subplot.

(ii) **Height** - (metres) measured or estimated to the nearest five percent.

(iii) **Diameter** (d.b.h.o.b.) - measured to the nearest 0.1 cm.

(iv) **Crown Position** - see Appendix 6(a).

(v) **Condition/Damage** - see Appendix 4(a).

(vi) **Control Rating** - see Appendix 4(a).

(vii) **Vegetative Reproduction** - the presence and number of adventitious shoots on the main stem or root collar region is tallied (living and dead shoots). The presence and number of sucker shoots (appropriate species only) is tallied within the 50 m² subplot (living and dead shoots). In the case of prolific suckering response, the size of the assessment plot may be reduced and noted. Sucker shoot data will consequently represent the suckering response within the subplot for the target tree species rather than the individual specimen.

2. Recording Conventions

All field notes and subplot measurements are recorded directly onto 80-column coding forms, the format of which is illustrated in Figure 4.
Crop Tree Specimen Description

Species  
(1) - Name Code  
(2) - Frequency  

Morphology  
(1) - Tree Height  
(2) - Tree Diameter  
(3) - Height of Live Crown  

Condition/Damage  
(1) - Foliage Condition  
(2) - Leader Shoot Condition  
(3) - Stem Condition Code  
(4) - Damage Cause  
(5) - Crop Tree Tolerance  

Target Tree Specimen Description

Species  
(1) - Name Code  
(2) - Specimen Location - Azimuth Bearing  
(3) - Specimen Location - Distance  
(4) - Frequency  

Morphology  
(1) - Tree Height  
(2) - Tree Diameter  
(3) - Crown Position  

Condition/Damage  
(1) - Crown Condition  
(2) - Stem Condition  
(3) - Damage Cause  
(4) - Control Rating  

Vegetative Growth  
(1) - Live Adventitious Shoots  
(2) - Dead Adventitious Shoots  
(3) - Live Root Sucker Shoots  
(4) - Dead Root Sucker Shoots  

FIGURE 4. Illustration of the field coding form layout for recording subplot data in stand release trials. Both data fields may be repeated on subsequent coding lines where assessment of more than one crop or target tree species is desired.
APPENDIX 6(a)

Crown Position Code for Crop and Target Trees in Stand Release Trials

The relative crown position index for crop trees is based on an adaptation from Devorkiantz et al (1943). The classification is based on degree of crown dominance in the stand. The observation code is as follows:

0 - open grown; isolated individuals.

1 - head dominants; those trees that dominate surrounding trees, with canopies above the general level of the stand canopy.

2 - strong dominants; those trees that are in competition with trees of the same crown class, but of poorer development.

3 - conditional dominants; those trees competing with trees of the same crown class and development and not in immediate danger of being crowded out.

4 - weak dominants and co-dominants, those trees competing with trees of better development.

5 - intermediates; those trees competing with trees of higher crown class and development, occupying small holes in the canopy.

6 - suppressed; trees definitely below the general level of canopy.
Crop Tree Encroachment Estimation
for Stand Release Trials\textsuperscript{8} (Walstad and Wagner, 1982)

Encroachment is defined as \textit{crown contact} between the crop tree canopy and surrounding target tree canopies. To estimate encroachment, visualize a cylinder projecting upwards at the widest periphery of the crop tree canopy, from ground level to the top of the target tree canopy. Estimate the percentage of the circumference of this cylinder dissected by target tree canopies that come into \textit{contact} with the crop tree canopy. This estimate may be easier if it is made in quadrants. The estimate is recorded as a percentage (nearest 10 percent) of the total circumference.

\textsuperscript{8} Ibid.
APPENDIX 6(c)

Crop Tree Vigour Code for
Stand Release Trials

The assessment of crop tree vigour is highly subjective. Assessment
criteria include foliage complement, live crown ratio, foliage colour,
and rate of growth. A five-class code is proposed as follows:

0 - dead.

1 - moribund (near death).

2 - repressed (low vigour, displays symptoms of severe
competition for light).

3 - moderate (medium vigour, displays symptoms of moderate
competition for light).

4 - good (displays level of vigour similar to free-growing
trees).

Revision and refinement of a morphologically-based vigour assessment may
be possible as experience accumulates in stand release treatments.
APPENDIX 7

Level B Vegetation Management Trial
Project Records Format\(^9\) (Walstad and Wagner, 1982)

Site Description

1. Location map and road log:

2. Elevation _________________________

3. Aspect ___________________________

4. Subzone __________________________

5. Association _______________________

6. Soil description:

7. Vegetation species inventory:

\(^9\) Ibid.
8. Block and plot position within the opening (include scale and north arrow):
Site History

1. Original stand
2. Year and season of logging
3. Site preparation or broadcast burning and year
4. Date of planting (month and year)
5. Species, stock type, and provenance
6. Other silvicultural activities
7. Industry or district contact
Herbicide Treatment

1. Herbicide
   a. trade name
   b. formulation
   c. lot number
   d. application rates

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<th>Rate</th>
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<td>Control</td>
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<tr>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

2. Ground treatment
   a. equipment make and model
   b. propulsion (if any)
   c. nozzle characteristics
   d. pressure
   e. delivery rate

3. Aerial treatment
   a. helicopter/sprayer model
   b. boom width
   c. nozzle characteristics (size, type, number, orientation, capacity)
   d. pressure
   e. delivery rate
   f. application speed (ground speed)
   g. application altitude
   h. swath width
   i. calibration check
4. Environmental conditions

<table>
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<th>After treatment</th>
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</tr>
<tr>
<td>RH (%)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Wind speed (mph)</td>
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<td>Wind direction</td>
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<td>Rainfall (in.)</td>
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<tr>
<td>Presence of dew</td>
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<td>Plant moisture status</td>
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<tr>
<td>Plant phenology</td>
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</table>

major target species 1  
2  
3  

minor species 1  
2  
3  

5. General comments
Non-Herbicide Treatments

1. Treatment method(s)

2. Treatment prescriptions/specifications

3. Timing of treatment(s) and target plant phenology

4. Production rates achieved

5. Costs incurred

6. General comments