



Australian Government
**Australian Pesticides and
Veterinary Medicines Authority**



GUIDELINES FOR EFFICACY EVALUATION OF HERBICIDES

Weeds in Australian Forests

SEPTEMBER 2009

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SPECIFIC SCOPE

This guideline describes the conduct of trials for the efficacy evaluation of herbicides in Australian forests. The guideline is based broadly on the European and Mediterranean Plant Protection Organisation (EPPO) Standard, PP 1/116(3), *Efficacy Evaluation of Herbicides- Weeds in Forests* and is adapted to reflect forestry practices in Australia.

BACKGROUND

Herbicides are used in Australian forestry to ensure that trees meet both silvicultural and commercial objectives without impediments of competitive vegetation.

The efficacy evaluation of herbicides involves a program of trials that assess weed control, selectivity and safety to the tree crop. This does not require the complete elimination of weeds, but rather the management of competitive weed infestations. These trials must ultimately demonstrate that the proposed product will perform in terms of efficacy and tree safety, as claimed on the proposed label for that product.

This Guideline supersedes the Australian Weeds Committee's Guidelines, *Field Evaluation of Herbicides* (1979) and *Herbicide Efficacy and Tolerance Data in Clearance and Registration Submissions* (1991) as it was necessary to replace these with a single, updated document to reflect current Australian forestry practices and Australian Pesticides and Veterinary Medicines Authority (APVMA) registration requirements. Other requirements apply to the regulation of agricultural permits and products in relation to environment and human health, identified in the APVMA Manual of Requirements and Guidelines (MORAG):

<http://www.apvma.gov.au/industry/MORAG.shtml>

As required, this Guideline will be revised with input from the Forest Industry and such other organisations and individuals the APVMA deems necessary.

1. EXPERIMENTAL CONDITIONS

Herbicides are primarily used in forestry to reduce weed competition during the establishment phase. The wide range of operational practices within the Australian forest industry necessitates the availability of a range of trial types that use a range of application methods, including aerial and ground based techniques. These trials include:

- a) cleared land, 1st or 2nd/or later rotation (1R or 2R/later) prior to planting;
- b) pre-planting;
- c) post-planting trials or combination of b) and c);
- d) removal of planted or naturally regenerated wildling trees, coppice trees and undesirable regrowth from cut stumps;
- e) thinning;
- f) plantation rescue trials under or over mature or established trees;
- g) noxious or woody weed control in cleared land or plantation trees; and
- h) other.

1.1 Selection of tree species and cultivar

This Guideline relates to all forestry tree species that may be grown in Australia. Where it can be demonstrated that different cultivars of a species or different species of a genus, which are grown under comparable environmental and cultural conditions, show similar herbicide tolerance, trial results from one cultivar or species may be used to apply to others. If similar tolerance cannot be demonstrated, specialised trials should be considered.

1.2 Weed situation

1.2.1 Weed control testing of individual products

Trial plots should be known to carry an appropriate weed diversity, or potential weed diversity from seed or root material, corresponding to the specific weed control properties of the test product (e.g. monocots and/or dicots, annuals and/or perennials). If the specific weed control properties of the test product are known, additional trialling of mixtures to cover the weed spectrum may also be included.

Target weeds should be at sufficient density to challenge the herbicide and be at the growth stage(s) claimed on the product label. Any proposed critical comments or other label instructions related to efficacy or crop safety must be tested. The APVMA Part 8 Efficacy and Crop Safety instructions (see link below) describes the general requirements and the format to be used for submitting efficacy and crop safety data in support of the registration of agricultural chemical products:

http://www.apvma.gov.au/MORAG_ag/vol_3/part_8_efficacyandsafety.pdf

1.2.2 Selectivity testing

For type a), b) and c) trials, plots should preferably be as free from weeds as possible, where only selectivity (phytotoxicity) trials are to be conducted. Standard or local pre-trial clean-up herbicide applications may be used where it can be demonstrated that these do not interfere with trial treatments.

Assessment of the test product(s) safety to trees (phytotoxicity) could be performed in the same trial plot in which weed control is assessed.

Supporting data on herbicide selectivity may be generated in laboratory and greenhouse trials.

1.3 Trial conditions

Trials should be carried out under typical field conditions. Cultural conditions, e.g. soil type, site preparation including cultivation and fertilization, should be uniform for all trial plots and should conform to standard forestry practice. At planting, trees should be to regional specification standards and in healthy condition. They should be of uniform age, even growth and without undue adverse effects from weed competition. In all cases, records must state the condition of crop trees (e.g. estimated average height, diameter or circumference, vigour). For phytotoxicity assessment, record measurements on individually marked trees.

Trial treatments and controls should be replicated in both space and time, ie. across a range of different sites, environmental conditions and at different times (seasonal or years), until quantitative data demonstrates consistent results or control is achieved for trial types d), e), f) and g). If necessary, see EPPO Standards PP 1/181(3) and 1/226(1) in Section 6 for further details.

Where products may be used more than once it is useful to extend individual selectivity trials over 2 years or more, in order to detect and report any cumulative phytotoxicity effects.

1.4 Trial design and layout

Treatments: Test product(s), Reference product(s) and untreated control plots must be arranged in a suitable trial design. With tests on perennial weeds, it may be necessary to use irregularly arranged plots to cover separate infestations.

For trials on suckering species, e.g. type d), g) and h) trials, treatments should be separated to avoid interference from other treatments.

For type a), b) and c) trials, each plot size (net) must be at least 50 m².

For type d), e), g) and h) trials, at least 15 separate trees / woody weed infestations must be sampled.

Replicates: A minimum of three replicates should be undertaken, however four replicates would eliminate some risks if a replicate is compromised. The number of replicates must also consider the major forestry regions in which the product will be registered. In case a replicate or trial site is lost due to environmental or pest factors, it may be better to locate trials in four regions with three replicates, rather than three regions with four replicates.

Further information on the general design and analysis of efficacy evaluation trials including good experimental practice may also be found in EPPO Standards 1/152(3) and 1/181(3) in Section 6.

For aerial (fixed or rotary wing) trials, at least a tank load is required for efficiency reasons and plots designed to ensure appropriate spray coverage is achieved.

2 APPLICATION OF TREATMENTS

2.1 Test product(s)

The products under investigation should be named or coded formulated product(s) and should be applied strictly as specified by the agricultural chemical company for the intended use (e.g. with an adjuvant). The product evaluated in the research trials must be (or must be demonstrated to be) equal to the formulated product that is (or is to be) registered with the APVMA.

2.2 Reference product(s)

Untreated controls (Type 1 controls) must be included in every trial as these are the absolute point of reference.

Reference product(s) (Type 2 controls) should be a product or mixture of products that conform to local practice or industry standards. Reference product(s) may be the industry (or a local) standard and are usually included in trials so that statistical comparisons can be made against the test products. Reference product(s) should be known to be satisfactory in practice under the plant health and environmental (including climatic) conditions in the area of intended use. Time of application and method of application should be as close as possible to those of the test products. If this is not possible, the reference product(s) and test products should be applied according to their specified use. In some cases, e.g. for new tree species, there may be no reference product.

2.3 Mode of application

The application of herbicides should conform to good forestry practice.

2.3.1 Type of application

The type of application should be as specified for the intended use. Normally these include a spray or granular application to the treatment area, surface of the bark, cuts in the bark (notches or frills), cut stumps or to suckers. Other methods may be developed for specific application needs.

2.3.2 Type of equipment

Application(s) should be made with suitable equipment to provide an even distribution of product across the whole plot or accurate directional application, where appropriate equipment equivalent to that intended for commercial or regional practice should be used.

Factors which may affect the herbicide efficacy and/or duration of weed control and/or selectivity (such as rate of use, application volume, operating pressure, nozzle type) should be chosen in relation to the intended use and best practice. This information should be included in the trial reports.

2.3.3 Timing and frequency of application

The number of applications and the timing of each application should be as specified for the intended use.

For type d) trials, weed trees may also be present. If herbicides are applied to the bark (basal bark treatment), cuts in the bark and/or via basal stem injection, the trunk diameter at breast height (DBH), trunk diameter at the base and the canopy circumference of all trees should be individually identified and measured. The same applies for the use of this technique for thinning crop trees (e.g. type e) trials).

For coppice trials (also type d) trials), a similar procedure may be followed. For multiple emerging coppice stems off-stump, the average height, age and number of treated coppice stumps should be recorded, or alternatively a suitable scaled assessment could be used. For aerial and machine ground based trials, removal of planted or naturally regenerated, wildling trees, coppice trees and undesirable regrowth from cut stumps, a sufficient number of replicate groups (3-5) of at least 15 trees of various heights should be selected across the treatment area.

If the timing of application is not specified for the intended use, it will depend on the aim of the trial and on the test product. The same product may be applied once or in successive applications, provided that such applications conform to the chemical manufacturer's specifications.

2.3.4 Rates and volumes

The product should normally be applied at the proposed label rate for the intended use, however it may also be useful to test at other rates. Rates at half and double the intended rate should normally be applied for a new product, to test both herbicide efficacy and tree phytotoxicity. Where a rate range is proposed, the maximum and minimum rates should be tested against the reason(s) for the different rates (eg. early vs. advanced weed growth stages, sandy vs. heavy textured soils). The reasons should be included as critical comments for the label.

In summary, the dosage applied should normally be expressed in grams or kilograms of active ingredient (a.i.) per hectare (g/ha or kg/ha) or grams, kilograms or litres of product per hectare (g/ha, kg/ha or L/ha), noting the concentration of active constituent(s) present. Spray volume per hectare should also be recorded (e.g. 200 L/ha). Trials should be conducted with water of known and appropriate quality.

Accidental or deliberate deviations from the intended dosage should be noted.

2.3.5 Data on other plant protection products

If other plant protection products (or biocontrol agents) have to be used during the trial period, these should be applied uniformly to all plots and in separate applications to that of the test and reference products, to avoid possible interference.

3 MODE OF ASSESSMENT, RECORDING AND MEASUREMENTS

3.1 3.1 Meteorological and edaphic data

3.1.1 Meteorological data

Rainfall and temperature data from the nearest meteorological station should be obtained for an appropriate period prior to and after the establishment of the trial. Under various Australian conditions the appropriate period may be days, weeks or even months and is important when assessing soil moisture or dryness, which in turn is likely to affect the growth and health of the crop and/or weeds and the action of the herbicide.

At the time of application of trial treatments, temperature, wind speed and direction, relative humidity, precipitation and cloud cover should be recorded. Any change in weather conditions that may affect treatments should also be recorded.

In a post-planting application over or under trees, wet tree and/or weed foliage should be noted (fog, dew and/or precipitation).

Throughout the trial period, extreme weather conditions, such as severe or prolonged drought, fire, flooding rains, frosts, hail or heavy snow that are likely to influence the results should also be noted. Grazing (rabbits, kangaroos) and insect damage should also be recorded.

3.1.2 Edaphic data

The following soil characteristics should be recorded: soil type/origin (to a specified national or international standard), moisture assessment (eg. dry, wet, waterlogged), organic matter content (eg. low, moderate, high) and pH. For further details, refer to EPPO Standards 1/152(3), 1/181(3) and 1/223(1) in Section 6.

3.2 Type, timing and frequency of assessment

The state of both weeds and crop at application and assessment should be recorded, including health, emergence and growth stage.

3.2.1 Type

3.2.1.1 Observations on weeds

For type a), b), c), g), and h) trials where herbaceous or shrubby weeds are principally concerned, the following should be seen to.

The weed population of a plot can be recorded in terms of numbers, percent cover or biomass. These may be assessed in absolute terms or estimated. Information should also be provided on the absolute level of weed infestation in the untreated and reference product(s) plots (absolute assessment or weed cover). In order to support the claims for use, individual weed species are to be identified at each assessment period.

Weeds should be listed using both botanical and common names. Using terms such as 'monocot', 'dicot', 'broadleaf' or 'grass' are not sufficient to support registration.

Previous research work in Australia has identified that weed cover greater than 10% of the plot area during the first season and into the second season demonstrates failure of the herbicide treatment (Baker *et al.* 1988, Ray *et al.* 1989, Dutkowski and Boomsma 1990, Richardson 1991, Wilkinson 1993 and Adams 1993). Research trials conducted in the 2008-09 season at Bombala, NSW (Radiata pine) and Bairnsdale, Victoria (Blue gum) showed that there was suitable correlation 4-5 months after planting between absolute (looking over the top of a quadrat) and estimated (looking at the entire plot from side-on or end-on) assessments of weed cover when weed cover was less than 30% of the plot area (see *Comparison of Assessments by two Independent Methods of Weed Cover*, Section 7). However, when weed cover was greater than 30% of the plot area, absolute assessment under estimated weed cover compared to estimated assessment, probably due to parallax errors.

(a) Absolute assessment

Individual plants should be counted for each weed species. These assessments should be made on whole plots or randomly selected quadrats in each plot, because weed distribution is rarely uniform. As a minimum, absolute assessment of Type 1 and Type 2 (if included) controls are required at each assessment period.

(b) Estimation

Each treatment plot should be compared with an untreated plot and the relative weed population should be estimated. The assessment involves a general estimation of the total weed population and/or of individual weed species at each assessment, across the whole plot. The result may be expressed simply as a percentage estimation of weed cover for all treatment plots and Type 1 and Type 2 controls.

Assessment of treatment plots can be broken down to estimate percentages of individual major weed species and aggregated minor weeds OR a relative percentage based on the untreated control (for example, on a linear scale from 0% = no weeds to 100% = same weed infestation as untreated control). However, non-assessment of individual weed species will preclude those weed species from being identified on the product label.

Scaling methods may also be used e.g. an equivalent inverted scale may be used to express percent weed control (0% = no weed control and 100% = complete weed control). Any scales used should be described. The treatment area could also be broken into smaller quadrants to help quantify the percentages.

Whatever the method of assessment, symptoms of nil or any damage to the weeds should be accurately described, e.g. healthy, stunted, chlorosis, epinasty etc.

For trials of type c), woody weeds can be assessed following similar principals: assessment of average height, number or weight of suckers formed, will generally be appropriate. An assessment of vigour relative to the untreated control may also be useful.

For trials of type d), damage to wildlings or coppice can be assessed on the basis of height above ground or from the stump e.g. 0-50 cm, 50-100 cm, 100-200 cm, >200 cm, assessing damage from killed (100% for a height class) to a % damage scale which should be described.

For trials of type e), count the number of trees killed.

3.2.1.2 *Observations on trees*

Phytotoxicity should be scored as follows:

- a) If the effect can be counted or measured, it should be expressed in absolute figures, e.g. mortality count related to number of trees per treatment. These should be compared with the measurements of marked trees made before application (see Section 1.3)
- b) In other cases the frequency and degree of damage should be estimated using an appropriate scale, e.g. % defoliation or scorch/chlorosis, stunting, epinasty.
- c) For stump treatments, the possibility of 'flashback' – root contact transfer of herbicide – should be noted.
- d) Care should be exercised to avoid similar non-phytotoxic effects arising from 'wet feet', drought, frost, nutrient deficiencies, fertiliser placement, browsing by animals, birds and insects, poor seedling quality/ planting and other unintended effects, by comparison with untreated controls, other treatments and other plantation trees.

3.2.2 Time and frequency

For type a), b), c), g), and h) trials, where pre-planting and early post-planting treatments are applied to bare soil from late autumn through winter, assessments should be commenced around mid-spring. However, if weed cover has developed on untreated controls or other pre-planting treatments, an assessment of these may be advisable earlier e.g. when post-planting treatments are applied in the same trial. This may vary in cooler climates where spring planting does occur (e.g. Tasmania). Where labels claim periods of seasonal application or efficacy, trials must be conducted and reported on during these periods to support these claims.

For type a), b), c), g), and h) trials, where pre-planting and early post-planting treatments are applied from late autumn through winter to sites which contain live weeds, (not bare ground where a test of the knockdown or the knockdown and residual control efficacy of the herbicide being tested is a required part of the trial design), assessments should commence immediately prior to or at the time of treatment application.

In the temperate regions, further assessments should be carried out prior to annual weed senescence in early summer, and again in autumn, the timing of which may be varied depending climatic conditions such as rainfall events following summer drought.

Timing of assessments for trials will need to be more frequent in sub-tropical and tropical regions because weed development and tree growth is more rapid.

For type d), e), f) and h) trials, such as wildling trials, assessments should be on the basis of determining the efficacy (e.g. if a later assessment shows little change from (an) earlier assessment(s), there is no point in continuing). Also in woody and noxious weed trials where weeds may be dormant due to environmental effects, timing of assessment may need to be varied until weeds recover.

Table 1: Approximate timing advice for assessing different trial types

TYPE OF TRIAL	1ST ASSESSMENT	2ND ASSESSMENT	3RD OR LATER ASSESSMENTS
On bare ground, pasture weed sites- all treatments	Weed emergence by mid-spring	Early summer prior to annual weed senescence	Autumn, variable Tree measure at age 1 as a minimum and 2 years as an affirmation of the growth
Pre and post planting trials at establishment where treatments are not applied to bare ground.	At or immediately prior to treatment application	Mid spring to early summer prior to annual weed senescence (weed specific)	Autumn, variable Tree measure at age 1 as a minimum and 2 years as an affirmation of the growth
Wildling, woody weed, coppicing, thinning trials including aerial trials	Within 1 month from treatments or other recognized scheduling	Within 2-3 months or other recognized scheduling	As required or other recognized scheduling. Weed and tree species dependent
Rescue trials	Within 6-8 weeks after treatments		
Trials under mature stands	Within 1-3 months from treatments	6 months after treatment	12 months after treatment
Noxious weed control trials	Base on expected time for herbicide activity to be apparent	As required. Weed and tree species dependent	As required. Weed and tree species dependent

Note: Variations may be acceptable due to Australia's climatic variation and trial objectives. Any such variations and objective must be documented adequately.

3.3 Effects on other organisms

3.3.1 Effects on other pests

Any observed effects, positive or negative, on the incidence of other pests should be recorded.

3.3.2 *Effects on other non-target organisms*

Any observed effects, positive or negative, on naturally occurring or introduced pollinators or natural enemies should be recorded, as identified in MORAG. Any other environmental effects should also be recorded, especially on wildlife, waterways etc.

3.4 Quantitative and qualitative recording of yield

There is no requirement to record these observations.

4 RESULTS

Results should be reported in a systematic form and the report should include an analysis and descriptive evaluation. The original data should be tabulated. Statistical analysis should be used for growth data, and for analysis of wildling, woody weed, coppicing and thinning trials (for further details see Section 7, *Example Report Template 2009*).

If further guidance is needed, refer to EPPO Standard, PP 1/152(3) in Section 6 and related documents as listed in Section 7.

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8 GLOSSARY

1st R, 2nd R	1st rotation, 2nd rotation
APVMA	Australian Pesticides and Veterinary Medicines Authority
AWC	Australian Weeds Committee
EPPO	European and Mediterranean Plant Protection Organisation
MORAG	Manual of Requirements and Guidelines
Type 1 controls	untreated plots (no herbicide treatment)
Type 2 controls	reference product(s) plot (industry standard herbicide treatment)
