Collaboration for Environmental Evidence
Library

CEE review 04-003

ARE CURRENTLY RECOMMENDED HERBICIDES EFFECTIVE FOR CONTROL OF RAGWORT (SENECIO) SPECIES?

Systematic Review

ROBERTS, P.D. & PULLIN, A.S.

Centre for Evidence-Based Conservation - School of Biosciences - The University of Birmingham – Edgbaston – Birmingham - B15 2TT - U.K.

Correspondence: *pdr387@bham.ac.uk*
Telephone: 0121 4144090

Protocol published on website: 28th June 2004 -Review posted on website: December 2004

Cite as: Roberts, P.D. & Pullin, A. S. 2004. Effectiveness of the control of ragwort (*Senecio*) species: "Are currently recommended herbicides effective for control of ragwort (*Senecio*) species?" CEE review 04-003 (SR5a). Collaboration for Environmental Evidence: www.environmentalevidence.org/SR5a.html.

SUMMARY

BACKGROUND

Ragwort (*Senecio* spp.) is poisonous and can have lethal effects on grazing animals, particularly horses. In the UK, as a result of The Ragwort Control Act 2003, landowners are expected to manage common ragwort (*S. jacobaea*) infestations so that they do not spread to adjacent sites. This systematic review, by the use of explicit methodology to capture and evaluate primary evidence, provides an evaluation of the effectiveness of the herbicides available to control *Senecio* species and highlights knowledge gaps within this area requiring further research.

OBJECTIVE

To assess the effectiveness of currently available and recommended herbicides documented for the control of ragwort species.

SEARCH STRATEGY

Electronic databases: ISI Web of Knowledge (WoK) containing ISI Web of Science and ISI Proceedings; Science Direct; JSTOR; Index to Thesis; UMI ProQuest Digital Dissertations; COPAC (incl. British Library); Natural History Museum Library; AGRICOLA and SCIRUS. English Nature (EN); Countryside Council for Wales (CCW) and Scottish Natural Heritage (SNH) publications were all searched online.

Other searches: Additional references not captured by the initial searches, were located via the inspection of all reference lists of studies accepted at full text.

SELECTION CRITERIA

All primary, quantitative studies and reports comparing a herbicide application (treatment plot) against no treatment (control plot) were included within the systematic review when focused upon one or more of the following species: common ragwort (*S. jacobaea*); marsh ragwort (*S. aquaticus*); Oxford ragwort (*S. squalidus*) or hoary ragwort (*S. erucifolius*).

DATA COLLECTION AND ANALYSIS

Both reviewers assessed study inclusion/exclusion, methodological quality & data extraction. Any discrepancies were resolved by discussion. Information on the population focus, methodology, interventions and outcomes were abstracted from the original studies into a specially designed, pre-tested spreadsheet. Data synthesis using standardised mean difference (SMD), random effects model meta-analysis and linear regression was performed by one reviewer, with the results being discussed by both reviewers.

MAIN RESULTS

All the meta-analyses concerning the mortality datasets show that the herbicides: 2,4-D, Asulam, MCPA, Clopyralid, Triclopyr, Picloram, Flazasulfuron, Chlorsulfuron, Metasulfuron, 2,4-DB and the herbicide mixtures: 2,4-D/Dicamba and 2,4-D/Triclopyr are effective at increasing mortality of *S. jacobaea* compared to no treatment. However, not all herbicides are effective in reducing the population densities of ragwort species even over a one year period. Three herbicides to note are 2,4-D, Asulam and MCPA. Both 2,4-D and MCPA significantly reduce population density of *S. jacobaea* (for 2,4-D, SMD = -1.44: 95% confidence intervals [CI] = -2.49 to -0.51 and for MCPA, SMD = -1.26: 95% CI = -1.97 to -0.55) but not *S. aquaticus* (for 2,4-D SMD = -0.77: 95% CI = -1.62 to 0.08 & for MCPA, SMD = -0.50: 95% CI = -1.27 to 0.28). Asulam significantly reduces population density of *S. aquaticus* (SMD = -4.87: 95% CI = -6.54 to -3.20), but not *S. jacobaea* (SMD positive sensitivity analysis = -5.26: 95% CI =-16.59 to 6.06 and SMD negative sensitivity analysis = -5.18; 95% CI = -16.70 to 6.33).

	Species to control	
	S. jacobaea	*S. aquaticus*
Effective control significantly reduces species density	2,4-D MCPA	Asulam
Not effective does not significantly reduce species density	Clopyralid Asulam	2,4-D MCPA

REVIEWERS' CONCLUSIONS

The current evidence from all randomised control trials and control trials captured by the comprehensive search strategy suggests that either 2,4-D or MCPA will effectively increase mortality and reduce the population density of *S. jacobaea,* thus potentially providing effective control, however for reduction of *S. aquaticus*; Asulam applications appears more effective.

Further randomised control trials are required on the following areas of herbicidal control of ragwort (All new trials should be based on a suitably long time period):

1. **All herbicides with small sample numbers** within this systematic review
2. **Species specific trials** to determine a definitive list of which herbicide to use for the particular species which control of is required. (e.g. Asulam on *S. jacobaea* currently only have a small number of datasets; Clopyralid on *S. aquaticus* no data was found by the search strategy of the review).
3. **The methods of herbicide application**, data was lacking on the application of herbicides using spot spraying, rope wick and weed wiping.

Additional recommendations are made for more detail in the reporting of study site descriptions, experimental methodology and adverse effects.

CONTENT PAGE

Effectiveness of the control of ragwort (*Senecio*) species: Are currently recommended herbicides effective for control of ragwort (*Senecio*) species?

1. BACKGROUND

Common ragwort (*Senecio jacobaea*), Marsh ragwort (*S. aquaticus*), Oxford ragwort (*S. squalidus*) and Hoary ragwort (*S. erucifolius*) are all members of the *Asteraceae* family. All can be found growing as a component of many stands of natural and semi-natural habitats, throughout Europe and North America, Southern Australia and New Zealand (EN, 2003; Simpson, 1993). For further details of the autecology of each of the ragwort species see Grimes *et al*,. (1988).

Ragwort species, especially *S jacobaea,* are known to be toxic to grazing animals (Defra, 2003), whether freshly grazed by the animal or consumed within feed (dried grass) or foliage (silage, hay or haylage) it can cause morbidity and mortality to livestock and equestrienne species (EN, 2003). Therefore, *S jacobaea* is the only one of the four species to be included within the designation of the UK Weeds Act 1959 and the recent UK Ragwort Control Bill 2003. It has also been given "weed status" in Tasmania under the states Weed Management Act 1999, due to its impacts on agricultural productivity. All property managers are required by law to control outbreaks and spread. On a wider scale Senecio species are prohibited to be imported into or throughout both Australia and New Zealand (McLaren 2004 *pers comms*).

Numerous herbicides (such as 2,4-D, Dicamba, Clopyralid and MCPA) and application methods (such as weed wiping, spraying and granules) have been used in an attempt to control ragwort species. With all the choices and no clear recommendations to which are the most effective, it is possible that resources are being wasted by conservation agencies, farmers and land-owners, which could be allocated elsewhere.

By the use of explicit methodology, through comprehensive searches and detailed inclusion criteria, the data from primary research and trials were collated for the numerous herbicides that have been used to control ragwort species. Meta-analysis and sub-group analysis were used, where appropriate, to test effectiveness of each of the herbicides at controlling ragwort species. Recommendations for practical management and research are presented by firstly, the identification of those herbicides which are effective control agents and secondly, highlighting any knowledge gaps which could lead to the identification of further primary needs-led research.

2. OBJECTIVES

To evaluate the effectiveness of herbicides used for the control of ragwort (*Senecio*) species, by the use of datasets concerning measures of mortality rates and/or population density, following herbicide application.

To explore, when possible, the following reasons for heterogeneity among the datasets:

1. Species of ragwort
2. Dosage of the herbicide
3. Month of treatment
4. Time period between treatment and recording of results.

3. METHODS

3.1. Search Strategy for Identification of Studies

The following electronic databases were searched for the identification of a ragwort library of all possible relevant studies for this systematic review. All dates listed below show the years covered by that particular database.

1. **ISI Web of Knowledge** (**WoK**) using CrossSearch Form involving the searching of the following products:
   ISI Web of Science (1981 to present).
   ISI Proceedings (1990 to present).
2. **Science Direct** – Agricultural and Biological Sciences (1823 to present).
3. **JSTOR**.
4. **Index to Theses** (1970 to 2003).
5. **UMI ProQuest Digital Dissertations** (1950s to 2003).
6. **COPAC** – database of the 24 main British and Irish university libraries and the British Library and National Library of Scotland.
7. **UK Natural History Museum Library** (1980 to present + 80% prior).
8. **AGRICOLA** – two databases for the National Agricultural Library of America:
   Online Public Access Catalogue (books).
   Journal Article Citation Index (journals).
9. **SCIRUS** – Scientific Search Engine.
10. **Wildlink** – English Nature's Library Catalogue (only available on-site).

The following search terms were used on all the above electronic databases to identify the initial library of all possibly relevant studies. This created an initial general ragwort control library of studies, from which filtering for particular control methods could take place (section 3.2)

1. Ragwort AND Control
2. *Senecio* AND Control
3. Pulling AND (Ragwort OR *Senecio*)
4. Herbicide AND (Ragwort OR *Senecio*)
5. Spraying AND (Ragwort OR *Senecio*)
6. Wiping AND (Ragwort OR *Senecio*)
7. "Spot Treatment" AND (Ragwort OR *Senecio*)
8. Cutting AND (Ragwort OR *Senecio*)
9. Mechanical AND (Ragwort OR *Senecio*)
10. Biological AND Control AND (Ragwort OR *Senecio*)
11. Cinnabar AND Moth
12. *Tyria* AND *jacobaeae*
13. Ragwort AND "flea beetle"
14. *Longitarsus* AND *jacobaeae*

Searches on www.alltheweb.com were also constructed using the search terms below. In all cases only the website that was captured by the alltheweb search was assessed, no links were followed from identified sites. The first 50 websites were assessed for their relevance.

1. Ragwort + control
2. Ragwort + control + results
3. *Senecio* + control
4. *Senecio* + control + results

All of the electronic and web searches were initially completed in May 2004 with additional web searches being undertaken in August 2004.

Relevant organisations such as English Nature, Scottish Natural Heritage, Countryside Council for Wales, The National Trust and Wildlife Trusts were contacted and their website publication lists searched for pertinent grey literature or unpublished data.

3.2. Criteria for Inclusion of Studies within Systematic Review

The creation of this initial general library was generated from the 14 search terms across the 10 electronic databases (with the removal of all duplications) and the web based searches (as above). See figure one, for the number of articles identified at each step of the assessment for relevance.

To test for relevance of articles in the library, initial inclusion criteria for title and abstract assessment were developed. All studies to be included within the systematic review were required to be focused or partially focused on any ragwort species and also to contain any intervention which was undertaken to control/reduce the amount of ragwort present on the site/area. All studies which fulfilled this first assessment at title and abstract or those that lacked sufficient detail to make an assessment were placed in a second library for further assessment.

All reference lists of the remaining articles were checked to identify any articles missed in the initial search. These were added to the second library to give the total number of articles to be viewed at full text.

Full text assessment of the remaining articles was undertaken with the added inclusion criteria that all articles had to either contain a study comparator (i.e. two arms to the study: a treatment plot and a control plot) or compared two different sites. A random subset of 20 articles at full text inclusion was independently assessed by a second reviewer. Cohen's Kappa analysis was performed to test agreement between reviewers, with K = 0.87. Any disagreements on an article's inclusion/exclusion were resolved through discussion.

After full text assessment the final library of accepted ragwort articles was split in relation to the management intervention used to control ragwort species. For inclusion within this systematic review on the effectiveness of herbicides the following final inclusion criteria had to be fulfilled.

3.2.1. Types of Study

Studies had to contain a comparator, of no treatment/control plot for inclusion and subsequent data analysis. This criterion therefore allows for the inclusion of randomised control trials (RCTs), control trials (CTs) and site comparisons studies (SCSs). These were collated for each herbicide before the datasets were analysed.

Although stated in the protocol, time series data were not included within the meta-analysis due to the lack of a comparator component within the experimental design. All time series studies which have been identified by the search strategy are however presented in the study characteristic tables, so that the data are available for interested parties and for subsequent analysis (see Appendix 2; study number 14,18, 20, 23, 25, 26, 27, 29, 31, 35, 36 and 38).

3.2.2. Population Focus

All studies which mentioned one or more of the following species were considered for inclusion within the systematic review: common ragwort (*S. jacobaea*), marsh ragwort (*S. aquaticus*), Oxford ragwort (*S. squalidus*), hoary ragwort (*S. erucifolius*).

3.2.3. Interventions of Interest

The control of ragwort spp. with herbicide application against a comparator of no treatment. Studies were excluded if they compared herbicide application to another method other than no treatment (control plot/area/site).

All types of herbicide application methodology were included within this systematic review. These included broadcast spray, spot spray, weed wiping and rope wick application.

3.2.4. Desired Outcome Measures

The outcomes of interest for this review were:

i. Measures of the ragwort population densities
ii. Measures of the mortality of ragwort plants

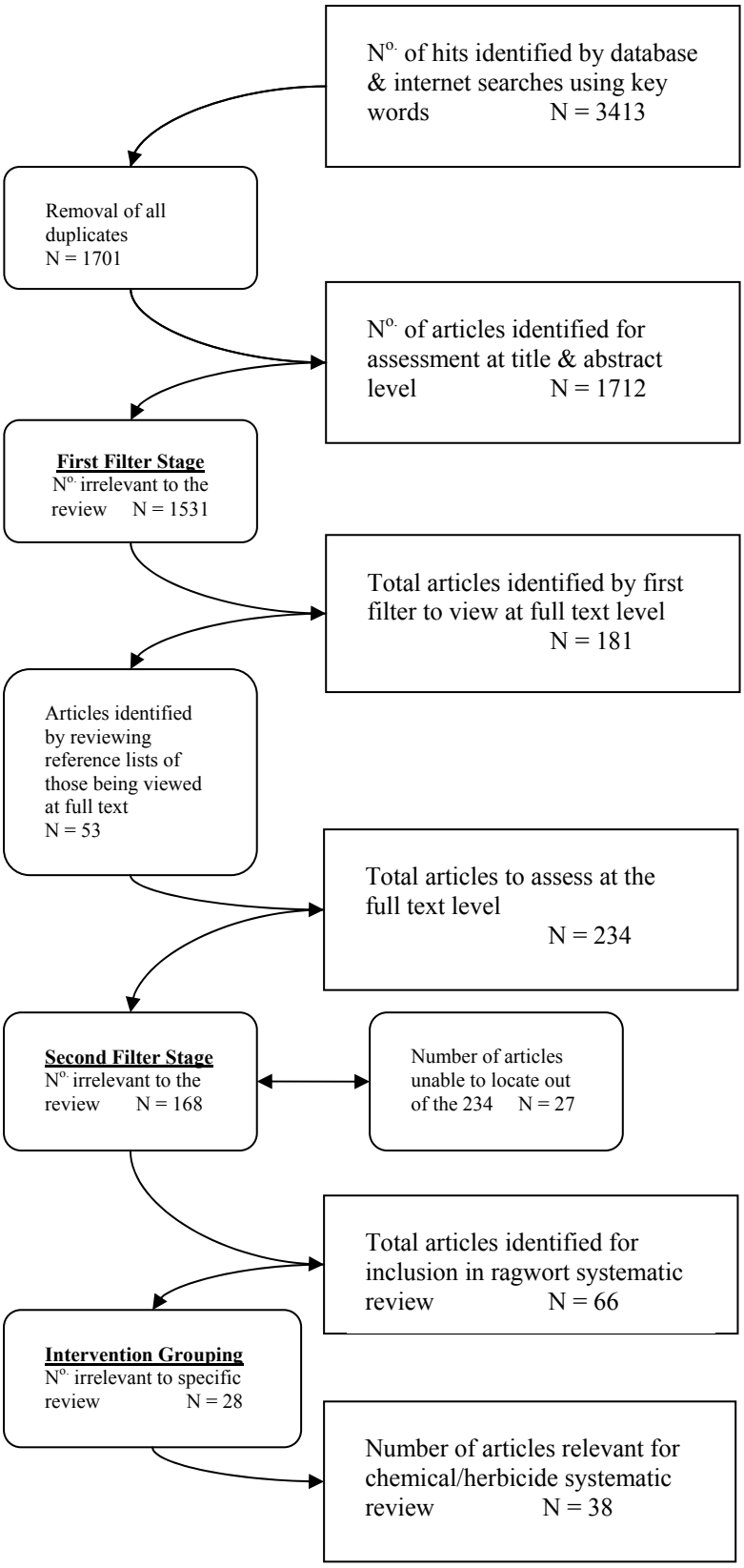

Figure 1: The process for studies to be included within systematic review, showing the numbers of studies at each stage.

3.3. Study Quality Assessment

The quality of each of the accepted studies (articles can report on one or more studies) was assessed in accordance with the study quality assessment instrument (Appendix 1) by one reviewer. The quality assessment involved looking at the experimental methodology used in each individual study. Details of the quality assessments for each of the individual studies are reported within the characteristic table (see Appendix 2).

3.4. Data Extraction

Initially data were extracted into a specially designed spreadsheet, recording the population focus, methodology, interventions and outcomes of the original studies. This assisted in the final assessment of inclusion/exclusion of studies to this systematic review. After the generation of the list of finally accepted studies was produced, the following data and study characteristics in addition to those above were extracted from all the included studies into both the specially designed spreadsheet and ultimately into each of the study characteristic tables:

Title, year of publication, year of experiment, site country & location, habitat, experimental area/plot size, species of ragwort, age of the plants, soil type, herbicide applied, month of herbicide application, method of application, dose applied, altitude of site, notable previous interventions undertaken, time of follow-up, any additional applications, other site activities during experiment, drop out, number of replicates, method of recording (use of scales, health scores etc.), outcome measure with related standard deviation values (e.g. % data, ragwort plants m^2, ragwort plants per plot etc.) and any adverse effects reported.

The form of the data extracted differed depending on whether the study was concerned with the mortality of ragwort or the population density after the intervention was undertaken. For population density, the data were in the form of ragwort plants per m^2 or ragwort plants per plot. For mortality, the data were in the form of % control or % kill of each ragwort species. In all cases, the mean number of replicates and standard deviation were required from both the treatment and control to allow meta-analyses to be performed on the datasets. The data extracted from the original studies and used within the meta-analyses are presented within the study characteristic tables (Appendix 2). All data were derived from the field/plot level to avoid pseudo-replication.

3.5 Data Checking

Attempts were made to contact the corresponding author of included studies if there were missing data or when clarification of results was required for subsequent analysis. In cases where authors were unavailable, a worse-case scenario measure of standard deviation was applied to the data extracted from the study. These datasets were included in the "all data" meta-analyses presented within section 5, (see Appendix 3 for the method used for calculating missing sd's).

3.6. Data Synthesis

The spreadsheets of extracted data were grouped by herbicide and used with StatsDirect™ programme for data synthesis. All outcomes were in the form of continuous data, which were pooled across trials using Standardised Mean Difference (SMD) meta-analysis (random effects model) (Sutton *et al.* 2000).

Sensitivity analyses were performed on the data to determine the effect of the inclusion of the following data characteristics:

1. Independent and non-independent datasets.
2. The "known data" where the mean, standard deviation and number of replicates are recorded from the original study and "all data", where the measure of standard deviation has been derived from another study within that particular analysis.

Non-independent datasets are defined as those studies which in their experimental design, compared a number of different treatments plots (e.g. herbicide doses), against only one control plot. All of these results could not be included within the analysis as they would affect the validity of the results. To overcome this, all non-independent datasets were included within the following analyses: Firstly the effect sizes were generated for all datasets. From this initial analysis, the most positive and most negative results from each of the non-independent datasets were included with the independent data in separate positive and negative sensitivity meta-analyses to assess the impact of the intervention.

Analyses of *a-priori* single-species subgroups were performed using SMD meta-analyses to determine whether the effectiveness of a particular herbicide varied according to the species that was being controlled. This tests the possibility that one species might be dominating the inclusive all species analyses, therefore masking the fact that a particular herbicide might not actually be effective at controlling all of the included ragwort species.

Regression analyses were performed (where sufficient data existed) to explore any possible ecological and methodological characteristics that could explain heterogeneity in results. *A-priori* factors which were considered to have possible importance included the dosage of the herbicide application, month of application and the length of follow-up.

4. RESULTS

4.1 Results of Search

Of the 38 studies containing information on the herbicide control of ragwort species, 26 fulfilled the inclusion criteria for meta-analysis, 12 were excluded due to being a time series without a comparator and are tabulated on their individual study characteristic sheet (Appendix 2). Of the 26 included studies, 14 were RCTs, 10 CTs and two SCSs. All included studies were published or reporting on experiments conducted between 1953 and 2004.

The studies were conducted in the following countries: New Zealand (n = 10), United Kingdom (n = 10), United States (n = 3), Australia (n = 1), Canada (n = 1) and Ireland (n = 1). These could be further split into the 106 independent datasets for use within the meta-analyses: UK (47), New Zealand (32), US (20), Australia (1), Canada (4) and Ireland (2).

Out of the 106 independent datasets that were extracted, only two of the desired ragwort species had data concerning their control; *S. jacobaea* (n = 104) and *S. aquaticus* (n = 2). The herbicides and mixtures that had independent datasets captured by the search strategy are listed in Table 1. All herbicides were considered for meta-analysis if there were two or more datasets available for synthesis.

Table 1: The herbicides and number of independent datasets which relate to each that are analysed for their effectiveness in controlling ragwort spp.

Herbicide	Mortality Datasets	Population Density Dataset
Asulam	14	8
2,4-D	36	28
2,4-DB	3	
(Mecoprop)CMPP		5
Dichlorprop		6
Chlorsulfuron	4	
Metasulfuron	4	
Flazasulfuron	6	
MCPA	2	20
Clopyralid	3	10
Picloram	5	
Glyphosate		6
Triclopyr	3	
2,4-D/Dicamba mix	3	
2,4-D/Picloram mix	4	
2,4-D/Triclopyr mix	2	

4.2. Results of Methodological Quality

The results of the methodological quality assessment are grouped by herbicide, highlighting some of the differing study characteristics which were combined within the respective meta-analyses and defined *a priori* as possible reasons for heterogeneity (Tables 2-4). Due to lack of reporting of the site and experimental design details within the original studies, insufficient data were available to investigate the *a priori* reasons for heterogeneity in all but the herbicides: 2,4-D; Asulam and MCPA.

Table 2: Details of studies contributing data to the meta-analyses for the application of 2,4-D on ragwort spp. The *a priori* reasons for heterogeneity are also presented for comparison.

HERBICIDE : 2,4-D	**DATATYPE:**	**Population Density Data**		
Study contributing datasets	Species (*S. jacobaea* or *S. aquaticus*)	Dose (kg a.i./ha)	Month of Application (relative to Winter Solstice)	Follow-up Period (days)
Courtney, A. D. & Johnston, R. (1976)	*S. jacobaea*	1.68 or 2.24	April – August	30 – 365
Dixon, F. L. & Clay, D. V. (2001)	*S. jacobaea*	2.1 or 2.3	March – May	60
Forbes, J. C. (1977)	*S. aquaticus*	1.4	April – May	90 – 425
Forbes, J. C., Kilgour, D. W. et al. (1980)	*S. jacobaea*	2.1	May	425
Forbes, J. C. (1982)	*S. jacobaea*	1.7	November	240
McClements, I. (1992)	1 *S. jacobaea* dataset & 1 *S. aquaticus* dataset	0.66	unknown	30
Shiban, A. (1976)	*S. jacobaea*	unknown	unknown	30
HERBICIDE : 2,4-D	**DATATYPE:**	**Mortality Data**		
Study contributing datasets	Species (*S. jacobaea* or *S. aquaticus*)	Dose (kg a.i./ha)	Month of Application (relative to Winter Solstice)	Follow-up Period (days)
Black, W. N. (1976)	*S. jacobaea*	2.2 – 4.4	June	unknown
Coles, P. G. (1967)	*S. jacobaea*	0.24	April – November	77 – 224
Eadie, I. M. & Robinson, B. D. (1953)	*S. jacobaea*	0.42	May	60
Fryer, J. D. (1953)	*S. jacobaea*	0.42 or 0.54	June	365
Harper, D. R. (1976)	*S. jacobaea*	3.4	May	90
James, T. K., Rahman, A. et al. (1997)	*S. jacobaea*	1.04	April	unknown
Martin, P., Thompson, A., et al. (1986)	*S. jacobaea*	1.0, 2.0 or 3.5	February	150 – 210
Naish, R. W. (1975)	*S. jacobaea*	2.0	unknown	180
Thompson, A. (1974)	*S. jacobaea*	0.6 or 1.5	May	425
Thompson, A. (1980)	*S. jacobaea*	0.75 or 1.5	May or November	330
Thompson, A. & Saunders, A. (1984)	*S. jacobaea*	0.9, 1.35 or 1.8	May	180
Whitson, T. D., Hawkes, B., et al. (1986)	*S. jacobaea*	0.135 – 0.36	March	90

Table 3: Details of studies contributing data to the meta-analyses for the application of Asulam on ragwort spp. The *a priori* reasons for heterogeneity are also presented for comparison.

HERBICIDE :	**Asulam**	**DATATYPE:**	**Population Density Data**		
Study contributing datasets	Species (*S. jacobaea* or *S. aquaticus*)	Dose (kg a.i./ha)	Month of Application (relative to Winter Solstice)	Follow-up Period (days)	
Forbes, J. C. (1977)	*S. aquaticus*	1.12 or 1.4	April – May	90 – 425	
Forbes, J. C. (1982)	*S. jacobaea*	1.7	November	240	
Shiban, A. (1976)	*S. jacobaea*	unknown	unknown	30	
HERBICIDE :	**Asulam**	**DATATYPE:**	**Mortality Data**		
Study contributing datasets	Species (*S. jacobaea* or *S. aquaticus*)	Dose (kg a.i./ha)	Month of Application (relative to Winter Solstice)	Follow-up Period (days)	
Appleby, A. P. (1979)	*S. jacobaea*	2.57	unknown	unknown	
Harper, D. R. (1976)	*S. jacobaea*	0.6 – 4.4	March – May	30 – 150	

Table 4: Details of studies contributing data to the meta-analyses for the application of MCPA on ragwort spp. The *a priori* reasons for heterogeneity are also presented for comparison.

HERBICIDE :	**MCPA**	**DATATYPE:**	**Population Density Data**		
Study contributing datasets	Species (*S. jacobaea* or *S. aquaticus*)	Dose (kg a.i./ha)	Month of Application (relative to Winter Solstice)	Follow-up Period (days)	
Courtney, A. D. & Johnston, R. (1976)	*S. jacobaea*	2.24	April – September	30 – 365	
Forbes, J. C. (1977)	*S. aquaticus*	1.4	unknown	90 – 555	
Forbes, J. C., Kilgour, D. W. et al. (1980)	*S. jacobaea*	1.85 or 1.98	May – June	425	
Forbes, J. C. (1982)	*S. jacobaea*	2.3	November	240	
McClements, I. (1992)	1 *S. jacobaea* dataset & 1 *S. aquaticus* dataset	1.22	unknown	30	
Shiban, A. (1976)	*S. jacobaea*	unknown	unknown	30	
HERBICIDE :	**MCPA**	**DATATYPE:**	**Mortality Data**		
Study contributing datasets	Species (*S. jacobaea* or *S. aquaticus*)	Dose (kg a.i./ha)	Month of Application (relative to Winter Solstice)	Follow-up Period (days)	
Eadie, I. M. & Robinson, B. D. (1953)	*S. jacobaea*	0.42	November	60	
Thompson, A. & Saunders, A. (1984)	*S. jacobaea*	0.94 – 1.87	unknown	180	

5. OUTCOME OF THE REVIEW

In what follows, the results for each herbicide are presented in tabular form with the main results presented in the text. For each herbicide the data for mortality rates and population density are presented when available. When possible these are further split into sub-group analyses for *S. jacobaea* and *S. aquaticus* individually.

Tables 5 to 13 show the overall pooled effect size for the meta-analysis, the 95% confidence intervals and significance. When non-independent data is present, sensitivity analyses were performed. This is when the most positive results (those that had the greatest effect from each dataset) or most negative results (those that had the least effect from each dataset) are re-analysed thus giving independent datasets for the herbicide.

Two types of data have been analysed when available – "known" and "all" data. These differ in characteristic due to the origin of their standard deviation measure – "known" data have all values taken from the original studies; "all" data have required a measure for standard deviation to be derived from the other studies involved within that specific meta-analysis (see Appendix 3 for details). This derived measure for the standard deviation gives the "all" datasets a more conservative measure for the effectiveness of the herbicide.

Throughout the results section both mortality and population density data are discussed:

For population density data, negative results = the herbicide was effective (i.e. reducing the population density) and positive results = the herbicide was ineffective (i.e. increasing the population density).

For mortality data, positive results = the herbicide was effective (increasing mortality) and negative = the herbicide was ineffective (decreasing mortality).

Please note that the analyses for each herbicide have been performed by comparing the treatment (herbicide) against no treatment (control) to derive effectiveness. Direct comparisons between herbicides using the output of the meta-analyses cannot be made – to perform this analysis the original studies would have been required to investigate herbicide A against herbicide B. The results of the resultant meta-analyses would then inform which of the herbicides was the most effective at controlling ragwort.

5.1 Single Herbicide Data

5.1.1. Herbicide: 2,4-D

Population Density Data

Six studies compared 2,4-D application to no treatment/control. From these six studies, 34 non-independent datasets (multiple plots, different doses compared to the same control) were extracted, from which 28 could be used in an independent analysis. Some of these datasets required a substitute measure for missing standard deviation ("All data"; see Appendix 3). From the 34 non-independent datasets, six had known measures of standard deviation ("Known data"), of which all six datasets could be used independently. Additionally, meta-analyses on five independent "known" datasets focused solely on *S jacobaea* and seven "all" datasets focused solely on *S. aquaticus* were performed.

When including both *S jacobaea* and *S. aquaticus* within the meta-analysis, 2,4-D application achieves a significant reduction in the population densities of ragwort species compared with the control (Table 5; "known data" SMD = -1.95: 95% CI = -3.39 to -0.51: p = 0.0078).

When species were analysed separately, 2,4-D application still achieves a significant reduction in population density of *S jacobaea*, (Table 5; "known data" SMD = -1.44: 95% CI = -2.49 to -0.39: p = 0.007) but not *S. aquaticus* (SMD = -0.77: 95% CI = -1.62 to 0.08: p = 0.0751). The latter is consistent with the 95% confidence intervals of the effect size (-0.77) crossing the line of no effects (-1.62 to 0.08).

Mortality Data

Twelve studies compared 2,4-D application to no treatment. From these 12 studies, 71 non-independent datasets (multiple plots, different doses compared to the same control) were extracted, from which 36 could be used in an independent analysis. Some of these datasets required a substitute measure for missing standard deviation ("All data"; see Appendix 3). From the 71 non-independent datasets, 25 had known measures of standard deviation, of which 16 datasets could be used independently ("Known data").

The resulting data show that 2,4-D application achieves a significant increase in *S jacobaea* mortality, irrespective of whether the most positive of negative non-independent datasets are combined with independent data (see Table 5).

Table 5: Meta-analyses results comparing the application of 2,4-D against no treatment (control)

The pooled effect size, 95% confidence intervals (CI) and DerSimmonian-Laird chi-squared significance (sign) are presented. Results for mortality data are positive for a treatment effect (i.e. 2,4-D application increases mortality). For population density data results are negative for a treatment effect (2,4-D application reduces the population density of ragwort species). Not required in the box = original meta-analysis was performed on independent data. Dashes represent when no data was available. For population density there are subgroup analyses for both *S. jacobaea* and *S. aquaticus* are presented.

		Known Data			All Data		
Species		Independent Data	Positive Sensitivity Analysis	Negative Sensitivity Analysis	Independent Data	Positive Sensitivity Analysis	Negative Sensitivity Analysis
Population Density Data							
Both *S. jacobaea* and *S. aquaticus*	**n** **Effect Size** **95% CI** **sign.**	6 -1.95 -3.39 to -0.51 p = 0.0078	Not required	Not required	-	28 -0.47 -0.85 to -0.09 p = 0.0159	28 -0.47 -0.85 to -0.09 p = 0.0163
***S. jacobaea* only**	**n** **Effect Size** **95% CI** **sign.**	5 -1.44 -2.49 to -0.39 p = 0.007	Not required	Not required	-	-	-
***S. aquaticus* only**	**n** **Effect Size** **95% CI** **sign.**	-	-	-	7 -0.77 -1.62 to 0.08 p = 0.0751	Not required	Not required
Mortality Data							
***S. jacobaea* only**	**n** **Effect Size** **95% CI** **sign.**	-	16 4.02 2.43 to 5.62 p <0.0001	16 2.70 1.38 to 4.02 p <0.0001	-	36 1.04 0.39 to 1.70 p = 0.0019	36 1.05 0.49 to 1.60 p = 0.0002

Heterogeneity

2,4-D Mortality Data

The original tests for heterogeneity from the meta-analysis of "all data" proved highly significant (Q = 266.242231; p < 0.0001) for variability between the studies contributing to the analyses. To explore possible explanations for this, the *a priori* defined reasons for heterogeneity were investigated using linear regression analysis (Table 6).

Table 6: Linear regression of the *a priori* defined reasons for heterogeneity.
For Prob>F; n/s = not significant, * = significant at 0.05, ** = significant at 0.01 and *** = significant at 0.001

Characteristic	Effect	R^2	F ratio	Prob > F	Linear fit
Dose	+	0.00	0.0204	n/s	Effect Size = 11.76 + 0.64 (dose)
Month of Spray	-	0.04	1.2692	n/s	Effect Size = 15.87 – 2.03 (month)
Follow-up	-	0.11	0.0825	n/s	Effect Size = 21.15 – 0.06 (follow-up)

The results for each of the linear regression analyses comparing the *a priori* reasons for heterogeneity showed non-significant results for all three characteristics (see Table 6).

5.1.2. Herbicide: Asulam

Population Density Data

Three studies compared Asulam application to no treatment/control. From these studies, 14 non-independent datasets (multiple plots, different doses compared to the same control) were extracted, from which eight could be used in independent sensitivity analyses. All of these datasets required a substitute measure for missing standard deviation ("All data"; see Appendix 3). From the 14 non-independent datasets, eight dataset were focused solely on *S. jacobaea* of which two were independent. In addition six independent datasets focus solely on *S. aquaticus*.

When including both *S. jacobaea* and *S. aquaticus* within the meta-analysis, Asulam application achieves a significant reduction in the population densities of ragwort species compared with the control irrespective of whether taking the most positive or negative datasets for analysis (Table 7).

When species are analysed separately, Asulam application still achieves a significant reduction in population density of *S. aquaticus* but not *S. jacobaea.* This is evident because the 95% confidence intervals of the effect size of both the sensitivity analyses for *S. jacobaea* cross the line of no effects (95% CI for: positive sensitivity analysis = -16.59 to 6.06 and negative sensitivity analysis = -16.70 to 6.33).

Mortality Data

Two studies compared Asulam application to no treatment/control. From which, 62 non-independent datasets (multiple plots, different doses compared to the same control). Some of these datasets required a substitute measure for missing standard deviation ("All data"; see Appendix 3). From the 62 non-independent datasets, 61 had known measures of standard deviation, of which 13 datasets could be used independently; these are referred to as "Known data".

Asulam application on *S. jacobaea* achieves a significant increase in mortality compared with the control irrespective of whether "known" or "all" data are used (see Table 7).

Table 7: Meta-analyses results comparing the application of Asulam against no treatment (control)

The pooled effect size, 95% confidence intervals (CI) and DerSimmonian-Laird chi-squared significance (sign) are presented. Results for mortality data are positive for a treatment effect (i.e. Asulam application increases mortality). For population density data results are negative for a treatment effect (Asulam application reduces the population density of ragwort species). Not required in the box = original meta-analysis was performed on independent data. Dashes represent when no data was available. For population density there are subgroup analyses for both *S. jacobaea* and *S. aquaticus* are presented.

		Known Data			All Data		
Species		Independent Data	Positive Sensitivity Analysis	Negative Sensitivity Analysis	Independent Data	Positive Sensitivity Analysis	Negative Sensitivity Analysis
Population Density Data							
Both *S. jacobaea* and *S. aquaticus*	**n** **Effect Size** **95% CI** **sign.**	-	-	-	-	8 -4.87 -7.35 to -2.39 p = 0.0001	8 -4.88 -7.42 to -2.34 p = 0.0002
***S. jacobaea* only**	**n** **Effect Size** **95% CI** **sign.**	-	-	-	-	2 -5.26 -16.59 to 6.06 p = 0.3624	2 -5.18 -16.70 to 6.33 p = 0.3778
***S. aquaticus* only**	**n** **Effect Size** **95% CI** **sign.**	-	-	-	6 -4.87 -6.54 to -3.20 p < 0.0001	Not required	Not required
Mortality Data							
***S. jacobaea* only**	**n** **Effect Size** **95% CI** **sign.**	-	13 116.86 83.47 to 150.24 p <0.0001	13 4.10 2.89 to 5.31 p <0.0001	-	14 92.07 72.12 to 112.02 p <0.0001	14 3.88 2.72 to 5.05 p <0.0001

Heterogeneity

Linear regression was undertaken to explore the possible reasons for heterogeneity (the amount of variability between studies in the estimates of effects, i.e. each studies point estimate), for both the population density and mortality datasets of Asulam application.

Population Density Data

The original test for heterogeneity from the meta-analysis of "all data" proved highly significant (Q = 7.442073; p = 0.0004) for variability between the studies contributing to the analyses. To explore possible explanations for this the following characteristics were investigated. **Please note** that for the regression results for density, a negative value of the slope (b) indicates a desired outcome as it results in the decrease of the population density.

Table 8: Linear regression of the *a priori* defined reasons for heterogeneity. For Prob>F n/s = not significant * = significant at 0.05 ** = significant at 0.01 and *** = significant at 0.001

Characteristic	Effect	R^2	F ratio	Prob > F	Linear fit
Dose	-	0.29	0.2183	n/s	Effect Size = 6.24 – 9.20 (dose)
Follow-up	+	0.00	0.9527	n/s	Effect Size = -5.97 + 0.0005 (follow-up)
Month of spray	Not performed due to missing information for half the dataset.				

The results for each of the linear regression comparing the *a priori* reasons for heterogeneity showed non-significant results for the two characteristics that had sufficient strata for analysis (see Table 8).

Mortality Data

The original test for heterogeneity from the meta-analysis of "all data" proved highly significant (Q = 795.026501; p < 0.0001) for variability between the studies contributing to the analyses.

Table 9: Linear regression of the *a priori* defined reasons for heterogeneity. For Prob>F n/s = not significant, * = significant at 0.05 ** = significant at 0.01 and *** = significant at 0.001

Characteristic	Effect	R^2	F ratio	Prob > F	Linear fit
Dose	+	0.29	24.35	***	Effect Size = 8.20 + 17.54 (dose)
Month of Spray	+	0.03	1.89	n/s	Effect Size = -19.22173 + 17.416044 (month)
Follow-up	-	0.07	4.58	*	Effect Size = 111.11 – 0.63 (follow-up)

From the linear regression analyses comparing the *a priori* reasons for heterogeneity (Table 9), the dose of the individual datasets point estimate was highly significant, showing that the higher the dose, the more effective the Asulam application. The length of follow-up showed a significant effect, with a negative relationship. The effectiveness of the Asulam is therefore shown to reduce the longer the follow-up monitoring period.

5.1.3. Herbicide: MCPA

Population Density Data

Five studies compared MCPA application to no treatment/control. From these studies, 26 non-independent datasets (multiple plots, different doses compared to the same control) were extracted, from which 20 could be used in an independent analysis. Some of these datasets required a substitute measure for missing standard deviation ("All data"; see Appendix 3). From the 26 non-independent datasets, seven had known measures of standard deviation, of which all seven datasets could be used independently; these are referred to as "Known data". Additionally meta-analyses were performed on "all" datasets focused solely with *S. jacobaea* with 13 independent datasets used in sensitivity analyses. Also a meta-analysis on seven "all" datasets focused solely on *S. aquaticus* was performed.

When including both *S. jacobaea* and *S. aquaticus* within the meta-analysis, MCPA application achieves a significant reduction in the population densities of ragwort species compared with the control (Table 10; "known data" SMD = -1.36: 95% CI = -2.05 to -0.67: p = 0.0001).

When species are analysed separately, MCPA application still achieves a significant reduction in population density of *S. jacobaea* (Table 10; "known data" SMD = -1.26: 95% CI = -1.97 to -0.55: p = 0.0005) but not *S. aquaticus* (SMD = -0.50: 95% CI = -1.27 to 0.28: p = 0.2085). The latter is consistent with the 95% confidence intervals of the effect size crossing the line of no effects (-1.27 to 0.28).

Mortality Data

Two studies compared MCPA application to no treatment/control. From these studies, four non-independent datasets (multiple plots, different doses compared to the same control) were extracted, from which two could be used in independent sensitivity analyses. Some of these datasets required a substitute measure for missing standard deviation ("All data"; see Appendix 3). From the four non-independent datasets, no datasets had known measures of standard deviation.

The resulting data show that MCPA application achieves a significant increase in *S. jacobaea* mortality irrespective of taking either the most positive or most negative datasets for sensitivity analyses (see Table 10).

Table 10: Meta-analyses results comparing the application of MCPA against no treatment (control)

The pooled effect size, 95% confidence intervals (CI) and DerSimmonian-Laird chi-squared significance (sign) are presented. Results for mortality data are positive for a treatment effect (i.e. MCPA application increases mortality). For population density data results are negative for a treatment effect (MCPA application reduces the population density of ragwort species). Not required in the box = original meta-analysis was performed on independent data. Dashes represent when no data was available. For population density there are subgroup analyses for both *S. jacobaea* and *S. aquaticus* are presented.

		Known Data			All Data		
Species		Independent Data	Positive Sensitivity Analysis	Negative Sensitivity Analysis	Independent Data	Positive Sensitivity Analysis	Negative Sensitivity Analysis
Population Density Data							
Both *S. jacobaea* and *S. aquaticus*	**n** **Effect Size** **95% CI** **sign.**	7 -1.36 -2.05 to -0.67 p = 0.0001	Not required	Not required	-	20 -0.66 -1.09 to -0.23 p = 0.0025	20 -0.66 -1.09 to -0.23 p = 0.0026
***S. jacobaea* only**	**n** **Effect Size** **95% CI** **sign.**	6 -1.26 -1.97 to -0.55 p = 0.0005	Not required	Not required	-	13 -0.73 -1.25 to -0.22 p = 0.0053	13 -0.73 -1.24 to -0.22 p = 0.0054
***S. aquaticus* only**	**n** **Effect Size** **95% CI** **sign.**	-	-	-	7 -0.50 -1.27 to 0.28 p = 0.2085	Not required	Not required
Mortality Data							
***S. jacobaea* only**	**n** **Effect Size** **95% CI** **sign.**	-	-	-	-	2 4.03 0.003 to 8.05 p = 0.0498	2 2.53 1.16 to 3.90 p = 0.0003

Heterogeneity

Population Density Data

The original test for heterogeneity from the meta-analysis of "all data" was not significant (Q = 9.830765; p = 0.957) for variability between the studies contributing to the analyses. However an examination of possible explanations for heterogeneity was still undertaken. **Please note** that for the regression results for density, that a negative value of the slope (b) indicates a desired outcome as it results in the decrease of the population density.

Table 11: Linear regression of the *a priori* defined reasons for heterogeneity. For Prob > F n/s = not significant, * = significant at 0.05, ** = significant at 0.01 and *** = significant at 0.001

Characteristic	Effect	R^2	F ratio	Prob > F	Linear fit
Dose	+	0.07	1.27	n/s	Effect Size = -1.68 + 0.51 (dose)
Follow-up	+	0.03	0.50	n/s	Effect Size = - 0.85 + 0.0008 (follow-up)
Month of spray	Not performed due to missing information for half the dataset.				

The results of the linear regression analyses testing the *a priori* reasons for heterogeneity were not significant for the two characteristics that could be analysed (see Table 11). There were insufficient data to perform linear regression on month of spray against the individual studies effect size due to half of the dataset not reporting date of MCPA application.

5.1.4. Herbicide: Clopyralid

Population Density Data

Two studies compared Clopyralid application to no treatment/control. From these studies, ten independent datasets were extracted for meta-analysis.

Data were only available for the meta-analysis of Clopyralid application on *S. jacobaea.* Clopyralid application does not achieve a significant reduction in the population density of *S. jacobaea.* (Table 12; "known data" SMD =-0.39: 95% CI = -0.99 to 0.21: p = 0.2037). This is consistent with the 95% confidence intervals of the effect size (-0.39) crossing the line of no effects (-0.99 to 0.21).

Mortality Data

One study compared Clopyralid application to no treatment/control. From this study, three independent datasets were extracted.

The resulting data show that Clopyralid application achieves a significant increase in the mortality of *S. jacobaea* (Table 12; "known data" SMD = 5.20: 95% CI = 1.36 to 9.03: p = 0.0079).

Table 12: Meta-analyses results comparing the application of Clopyralid against no treatment (control)

The pooled effect size, 95% confidence intervals (CI) and DerSimmonian-Laird chi-squared significance (sign) are presented. Results for mortality data are positive for a treatment effect (i.e. Clopyralid application increases mortality). For population density data results are negative for a treatment effect (Clopyralid application reduces the population density of ragwort species). Not required in the box = original meta-analysis was performed on independent data. Dashes represent when no data was available. In all cases the meta-analyses were performed on only *S. jacobaea* datasets.

		Known Data			All Data		
Species		Independent Data	Positive Sensitivity Analysis	Negative Sensitivity Analysis	Independent Data	Positive Sensitivity Analysis	Negative Sensitivity Analysis
Population Density Data							
***S. jacobaea* only**	**n** **Effect Size** **95% CI** **sign.**	-	-	-	10 -0.39 -0.99 to 0.21 p = 0.2037	Not required	Not required
Mortality Data							
***S. jacobaea* only**	**n** **Effect Size** **95% CI** **sign.**	3 5.20 1.36 to 9.03 p = 0.0079	Not required	Not required	-	-	-

5.1.5. Other Single Herbicide Datasets

The following herbicides only had one of either mortality or population density datasets available for meta-analysis; the results are presented in **Appendix 4** as a summary table. For all herbicides the number of datasets that contribute to the analyses are low ($n < 6$), therefore results of the meta-analyses should be treated with caution as more data are required before a definitive answer to the herbicide's effectiveness can be concluded.

Population Density Data – S. jacobaea only

The following herbicides had population density datasets available for meta-analysis:

1. Glyphosate
2. Dichlorprop
3. Mecoprop

Only Glyphosate showed a strong treatment effect, with results being statistically significant at $p = 0.0019$. Both Dichlorprop and Mecoprop derived very slight treatment effects with their confidence intervals intersecting the line of no effect (zero line). For both herbicides the density reduction was not significant ($p = 0.6807$ and $p = 0.4471$) respectively.

Mortality Data – S. jacobaea only

The following herbicides had mortality datasets available for meta-analysis. In all cases strong treatment effects were derived, with all observed increases in mortality being statistically significant at least at the $p = 0.05$ level.

1. 2,4-DB
2. Chlorsulfuron
3. Flazasulfuron
4. Metasulfuron
5. Picloram
6. Triclopyr

5.2 Herbicide Mixtures

5.2.1. Herbicide Mixture: 2,4-D & Dicamba

Population Density Data

One study compared the herbicide mixture 2,4-D & Dicamba application on *S. jacobaea* to no treatment/control. From this study eight independent datasets were extracted for meta-analysis. The application of 2,4-D & Dicamba does not achieve a significant reduction in the population density of *S. jacobaea.* (Table 13; "All data"; SMD = -0.50; 95% CI = -1.24 to 0.24; p = 0.1883). This is indicated by the 95% confidence intervals of the effect size (-0.50) crossing the line of no effects (-1.24 to 0.24).

Mortality Data

Two studies compared a 2,4-D & Dicamba herbicide mixture application to no treatment/control. From these two studies, four non-independent datasets (multiple plots, different doses compared to the same control) were extracted, from which three could be used in independent sensitivity analyses. Some of these datasets required a substitute measure for missing standard deviation ("all data"; see Appendix 3). From the four non-independent datasets, two had known measures of standard deviation, of which both datasets could be used independently; these are referred to as "Known data". The data show that the herbicide mixture achieves a significant increase in *S. jacobaea* mortality (Table 13; "Known data"; SMD =9.28; 95% CI = 4.46 to 14.09; p = 0.0002).

Table 13: Meta-analyses results comparing the application of Herbicide Mixtures against no treatment (control)

The pooled effect size, 95% confidence intervals (CI) and DerSimmonian-Laird chi-squared significance (sign) are presented. Results for mortality data are positive for a treatment effect (i.e. herbicide mixture application increases mortality). For population density data results are negative for a treatment effect (the herbicide mixture application reduces the population density of ragwort species). Not required in the box = original meta-analysis was performed on independent data. Dashes indicate no data were available. In all cases the meta-analyses were performed on only *S. jacobaea* datasets.

		Known Data			All Data		
Herbicide		Independent Data	Positive Sensitivity Analysis	Negative Sensitivity Analysis	Independent Data	Positive Sensitivity Analysis	Negative Sensitivity Analysis
Population Density Data – *S. jacobaea* only							
2,4-D & Dicamba	**n** **Effect Size** **95% CI** **sign.**	-	-	-	8 -0.50 -1.24 to 0.24 p = 0.1883	Not required	Not required
Mortality Data – *S. jacobaea* only							
2,4-D & Dicamba	**n** **Effect Size** **95% CI** **sign.**	2 9.28 4.46 to 14.09 p = 0.0002	Not required	Not required	-	3 12.42 0.49 to 24.34 p = 0.0412	3 11.77 4.44 to 19.10 p = 0.0017
Mortality Data – *S. jacobaea* only							
2,4-D & Triclopyr	**n** **Effect Size** **95% CI** **sign.**	2 2.28 0.44 to 4.11 p = 0.015	Not required	Not required	-	-	-
Population Density Data – *S. jacobaea* only							
2,4-D & Picloram	**n** **Effect Size** **95% CI** **sign.**	-	-	-	-	4 -30.81 -41.21 to -20.41 p < 0.0001)	4 -29.21 -39.09 to -19.34, p < 0.0001

5.2.2. Other Herbicide Mixtures

The following herbicides only had one of either the mortality or population density datasets available for meta-analysis; the results are presented in Table 13. For all herbicides mixtures the number of strata which contribute to the independent meta-analyses are low ($n < 4$), therefore caution should be exercised as more data are required before a definitive answer to the herbicide mixtures effectiveness can be concluded.

Population Density Data: 2,4-D & Picloram

Two studies compared the herbicide mixture Picloram & 2,4-D application to no treatment/control. From these studies, 13 non-independent datasets (multiple plots, different doses compared to the same control) were extracted, from which four could be used in an independent analysis. All of these datasets required a substitute measure for missing values for standard deviation ("All data"; see Appendix 3).

Data was only available for the meta-analysis of Picloram & 2,4-D application on *S. jacobaea.* Picloram & 2,4-D application achieves a significant reduction in the population density of *S. jacobaea.* (see Table 13).

Mortality Data: 2,4-D & Triclopyr

One study compared 2,4-D & Triclopyr herbicide mixture application to no treatment/control. From this study, two independent datasets were extracted.

Again data was only available for the meta-analysis of 2,4-D & Triclopyr application on *S. jacobaea.* The resulting data shows that the application of the herbicide mixture 2,4-D & Triclopyr achieves a significant effect of increasing *S. jacobaea* mortality (Table 13; "Known data" independent; SMD = 2.29; 95% CI = 0.44 to 4.11; $p = 0.015$).

6. DISCUSSION

The main aim of this review was to determine the effectiveness of currently used herbicides on the control of ragwort species. To achieve this we compared each of the herbicides separately using a treatment of the herbicide against no treatment (control). All the meta-analyses concerning the mortality datasets showed that all of the herbicides investigated within this systematic review proved effective at increasing the mortality of *S. jacobaea*.

When just considering the control of ragwort population density, the three main herbicides (2,4-D, Asulam and MCPA), all appear to be effective in reducing the population densities of ragwort species over a time period of one to two seasons. However, when the data are reanalysed for herbicide effectiveness against individual species, Asulam and Clopyralid are not effective in reducing the population of densities of *S. jacobaea* and 2,4-D and MCPA are not effective in the reduction of *S. aquaticus* population abundance. However, due to the small sample sizes for some of the single species analyses, caution should be emphasised in the usage of these conclusions. Further herbicide trials would benefit this area to allow a definitive answer for the effectiveness of these herbicides under these conditions.

Other herbicides that are not effective in controlling the population densities of *S. jacobaea* include Dichlorprop, Mecoprop and the 2,4-D & Dicamba mixture. There is an element of caution to be considered with the results surrounding these herbicides; as again they all had small sample sizes. Further primary research into trials of these herbicides is required to produce more definitive answers of these herbicides (see section 8.2 for further details).

For effective reduction of population density with Asulam and increased mortality with 2,4-D, the available evidence suggests ragwort plants should be treated during late April – early June (northern hemisphere) while the plant is in a vigorous growth phase prior to the final bolt and flowering. This may be due to the increase in growth allowing the translocation of the herbicide hormones from the foliage to the plants root system, which eventually dies (Black, 1976). Delaying application until after September allows older plants to flower and set seed, therefore serving as centres of new infestations. If the herbicide was applied during the plant's winter dormancy little translocation of the hormone is facilitated, therefore severely limiting the herbicides effectiveness in killing the plant.

The effectiveness of all herbicide applications was dependent on the weather within the first 12 hours after their application. This factor however, was only reported in a limited number of studies which seemed to have been affected by such conditions. Coles (1967) states that when rain fell within an hour of application the herbicide did not have a chance to dry on the plants foliage, therefore effectively reducing dosage delivered to the plant below sub-lethal levels. Forbes *et al.* (1980) also reported reduced control was observed when rain fell within 5 hours of either 2,4-D or MCPA application.

A reduction in herbage was observed by Forbes (1982) where the sward was rich in Asulam-sensitive grasses such as *Holcus* spp*., Agrostis* spp*. and Poa* spp. This is reduced when herbicide is applied with a weed wiper or careful spot spraying over

applications with broadcast sprayers. Unfortunately there were no independent datasets to perform further analysis on this hypothesis.

There is a difference in the results derived from "known data" and "all data" when calculating each studies' point estimate and its contribution to the final pooled effect size for the measure of the herbicides effectiveness. This is due to a number of factors. Firstly, the amount an individual study contributes to the overall effect size will be altered with "all data" due to increasing the number of studies within the meta-analyses. Secondly, using double the worst known measure of standard deviation as a substitute for unknown variance will have a further effect on lowering the derived effect of that studies' approximate point estimate and therefore reduce the overall pooled effect size for the herbicides effectiveness. Overall the use of "all data" is an over conservative (cautious) measure of herbicide effectiveness due to the missing measure of standard deviation (either not reported or the data is one treatment against one control) being derived from double that of the worst within that particular analysis.

Sources of Heterogeneity

It was expected that results would be affected by a number of variations in methodology or ecological characteristics. The observed variation in treatment effects was investigated for three of the herbicides with sufficient data points (2,4-D, Asulam and MCPA).

For the three characteristics that were tested (dose, month and follow-up), only the mortality data concerning Asulam application produced significant differences for both the dosage of the herbicide applied and the length of follow-up period. If the dosage applied is increased the mortality of ragwort is also increased and if the length of follow-up is long then the lower the treatment effect observed.

It should however be noted, by going back to the original studies, that higher dosages of herbicide, especially 2,4-D (4.5kg a.i./ha +) caused burning of grasses and severely reduce both white and red clover cover (Black 1976, Richards *et al.* 1983).

Sources of Bias

The majority of the trials reported in the original studies were small with less than 20 samples to derive an average for each of the trial arms. Also multiple doses from the same trials were compared to the same control plot therefore not allowing non-independent datasets to be taken from the original study. Reliance on small trials raises concerns about the effects of publication bias. Funnel plot assessment for all meta-analyses revealed evidence of this in the form of 'missing' data from negatively reporting studies. Although all funnel plots had clustering of datasets around the null (approximate studies point estimate = 0), there where very few datasets that showed an overall negative result for herbicide application. This was expected as authors do not always report small negative results as journals generally do not publish them.

Although this review did not exclude studies on the basis of language, the two studies captured by the search strategy as foreign texts could not be sourced for assessment for their inclusion within the systematic review.

7. REVIEWERS' CONCLUSIONS

7.1. Implications for Conservation

The suitability of a herbicide is dependent upon the ragwort species which is required to be controlled (see table 14 below): When controlling *S. jacobaea,* the use of the herbicides: 2,4-D, MCPA, Glyphosate and the mixture of 2,4-D/Picloram are all effective control agents. When controlling *S. aquaticus,* the herbicide Asulam is effective. Further to this, Clopyralid is ineffective at reducing *S. jacobaea* densities. Similar results for the ineffectiveness of Asulam applications on *S. jacobaea* densities were found, however caution should be used with this latter result due to the low sample size (n = 2) and nature of the data. The herbicides: 2,4-D and MCPA are ineffective at reducing *S. aquaticus* densities. Please note that the timescales for these calculations are based on the majority of datasets being taken over only one and two years.

Table 14: A guide to the herbicide to use to control either *S. jacobaea* or *S. aquaticus* densities.

	Species to control	
	S. jacobaea	*S. aquaticus*
Effective control significantly reduces species density	2,4-D MCPA	Asulam
Not effective does not significantly reduce species densities	Clopyralid Asulam	2,4-D MCPA

The recommended dosages of the products (either manufacturers or advice sheets from conservation organisations) should be adhered to with; either a reduction of dosage/ a specific application of the herbicide to the ragwort plant or an alternative method of control used to reduce the potential for damage to sensitive or priority species of conservation concern when located within the sward.

7.2. Implications for Research

This systematic review highlights major gaps in our knowledge on use of herbicides to control ragwort species. Further high quality research, (especially randomised control trials or control trials) are required to investigate the following herbicides and methods:

1. **The following herbicides should be the subject of further trials due to small sample numbers**
    a) Dichlorprop
    b) Mecoprop
    c) 2,4-D/ Dicamba mixture
2. **Further species-specific trials are required to determine a definitive list of herbicides to use for each species.** (e.g. Asulam on *S. jacobaea*; Clopyralid on *S. aquaticus*).
3. **The methods of herbicide application.** The overwhelming majority of studies captured were concerned with only broadcast spray – this is

inappropriate under in most nature reserves. Therefore further trials are called for to investigate methods sympathetic to non-target species (e.g. spot spraying or weed wiping).

Further to the three areas mentioned above, there is a requirement for additional detail to be included within the reporting of future herbicide trials. The methodological, ecological and physical characteristics of the trial and site should be included in detail within either the methods section of studies or as supplementary online material, which is becoming increasingly available. The inclusion of these more detailed descriptions of study characteristics would allow the investigation of possible reasons for heterogeneity (if any) to be performed on the results of meta-analysis.

In addition the reporting of adverse effects of a particular herbicide on none target species needs to be more explicit within studies. These should be reported for all species within the study area, including details of the damage caused with measurements of any population density or abundance reductions.

8. SOURCES OF SUPPORT

NERC and English Nature grants

9. ACKNOWLEDGEMENTS

The reviewers would like to thank Gavin Stewart, Claire Tyler and Zoe Davies for their support and initial proofing of this report.

Kevin Charman and John Bacon from English Nature and Matthew Oates from The National Trust for all their support and additional information.

We would also like to thank all the practitioners and policy makers who responded to our enquires.

10. REFERENCES

10.1. References to Studies Included in this Systematic Review

Appleby, A.P. (1979) Chemical control of tansy ragwort (Senecio jacobaea). *Symposium on Pyrrolizidine*, **23**, 161.

Black, W.N. (1976) Effects of herbicide rates and time of application on the control of tansy ragwort in pastures. *Canadian journal of plant science.*, **56**, 605-610.

Clay, D.V. & Dixon, F.L. (1998) The susceptibility of compositae weed species to clopyralid. *Tests of agrochemicals and cultivars. Supplement to Annals of applied biology, volume 132.*, **19**, 32-33.

Coles, P.G. (1967) Ragwort control with picloram. In Proceedings of the 20th New Zealand Weed and Pest Control Conference, pp. 32-36.

Courtney, A.D. & Johnston, R. (1976) An extended season of herbicides application for the control of Senecio jacobaea. In Br Weed Control Conf, pp. 611-618.

Dixon, F.L. & Clay, D.V. (2001). Effect of synthetic and natural-product herbicides on Senecio jacobaea (common ragwort). In *Bcpc Conference - Weeds 2001, Vols 1 and 2*, pp. 721-726. BRITISH CROP PROTECTION COUNCIL, Farnham.

Dixon, F.L. & Clay, D.V. (In press - 2004) Effect of herbicides applied pre- and post-emergence on forestry weeds grown from seed. *Crop Protection*, **In Press, Corrected Proof**.

Eadie, I.M. & Robinson, B.D. (1953) Control of ragwort by hormone-type weedicides. *Journal of the Australian Institute of Agricultural Science*, **19**, 192-196.

Forbes, J.C. (1977) Chemical control of marsh ragwort (Senecio aquaticus Huds.) in established grassland. *Weed research*, **17**, 247-250.

Forbes, J.C. (1978) Control of *Senecio jacobaea* (ragwort) by autumn or spring herbicide application. *Weed research*, **18**, 109-110.

Forbes, J.C. (1982) Evaluating herbicides for selective control of *Senecio jacobaea* in grass/clover swards. In In Proceedings of the 1982 British Crop Protection Confernce - Weeds, pp. 375-379.

Forbes, J.C., Kilgour, D.W., & Carnegie, H.M. (1980) Some causes of poor control of Senecio jacobaea L. by herbicides _Scotland, Ireland, grassland weed ragwort. In British Crop Protection Conference - Weeds, pp. 461-468, Brighton.

Fryer, J.D. (1953) The use of 2:4-D for the control of ragwort. In Proceedings of the 1st British Weed Control Conference, pp. 211-224.

Fryer, J.D. & Makepeace, R.J. (1956) Ragwort and its control. *Agriculture*, **63**, 65-69.

Harper, D.R. (1976) *Asulam for tansy ragwort control in alfalfa: Field efficacy and selectivity factors*. Ph.D., Oregon State University.

James, T.K. & Mortimer, J. (1983) Control of ragwort and nodding thistle in lucerne with hexazinone. In Proceedings New Zealand Weed and Pest Control Conference, Vol.?36th, pp. 17-20.

James, T.K., Rahman, A., & DeJong, P. (1997). Flazasulfuron for control of ragwort (Senecio jacobaea) in pasture. In *Proceedings of the Fifteenth New Zealand Plant Protection Conference*, pp. 477-481. NEW ZEALAND PLANT PROTECTION SOC, Rotorua.

Lawson, S. (1982) *An investigation into the viability of ragwort (Senecio jacobaea L.) seeds from plants treated with herbicides during flowering*. Honours dissertation. Aberdeen University.

Makepeace, W. & Thompson, A. (1982) Ragwort control using a rope wick applicator. In Proc. 35th New Zealand Weed and Pest Conference, pp. 256-260.

Marrs, R.H. (1985) The effects of potential bracken and scrub control herbicides on lowland Calluna and grass heath communities in East Anglia, UK. *Biological Conservation*, **32**, 13-32.

Martin, P., Thompson, A., Saunders, A.E., & Rahman, A. (1986) Effect of plant type on the response of ragwort to rates and times of 2,4-D application. *Proceedings New Zealand Weed and Pest Control Conference. July*, **39**, 179-182.

McClements, I. (1992) *Marsh ragwort (Senecio aquaticus) biology and control*. Ph.D., Queen's University Belfast, Belfast.

Murphy, J. (2000) Ragwort Control. Aventis Environmental Science.

Naish, R.W. (1975) Dowco 290 --a new growth regulator herbicide. In Proc N Z Weed Pest Control Conf 28th, pp. 177-180.

Radcliffe, J.E. (1969) Ragwort control. *New Zealand journal of agriculture*, **119**, 80-83.

Richards, M.C., Swift, G., Cleland, A.T., & Davies, D.H.K. (1983) Evaluation of 3,6-Dichloropicolinic Acid, Triclopyr, 2,4-D Ester and Mcpa, Alone and in Mixtures, for Senecio-Jacobaea Control in Grassland. *Annals of Applied Biology*, **102 Supplement**, 104-105.

Schmidl, L. (1964) Aerial spraying of ragwort in Victoria. *Journal of Agriculture, Victoria*, **62**, 445-450.

Shiban, A. (1976) *Effects of herbicides on ragwort*. M.Sc., Aberdeen.

Taylor, R.L. (1973) Control of ragwort. In Proc New Zealand Weed Pest Control Society, pp. 50-52.

Thompson, A. (1974) Herbicide effects on ragwort and pasture. In Proceedings of the 27th New Zealand Weed and Pest Control Conference, pp. 90-93.

Thompson, A. (1977) Herbicides for the spot treatment of ragwort in pasture. In Proceedings of the 30th New Zealand Weed and Pest Control Conference, pp. 34-37.

Thompson, A. (1980) Ragwort population and control studies. In Proceedings of the 33rd New Zealand Weed and Pest Control Conference, pp. 55-62.

Thompson, A. (1983) Pastrure weed control by rope wick applicator. In Proc. 36th New Zealand Weed and Pest Control Conference, pp. 96-98.

Thompson, A. & Saunders, A. (1984) A comparison of 2,4-D and MCPA, alone and in combination, for the control of ragwort. *Proceedings New Zealand Weed and Pest Control Conference*, 33-36.

Thompson, A. & Saunders, A.E. (1986) The effect of fertiliser on ragwort in pasture. *Proceedings New Zealand Weed and Pest Control Conference. July*, **39**, 175-178.

Watt, T.A. (1984) The effect of propyzamide and fertiliser on the establishment of ragwort in grassland. *Aspects of applied biology*, **5**, 109-116.

Whitson, T.D., Hawkes, B., Brown, J., Humphrey, D., & Langland, D. (1986) Effect of herbicide treatments on tansy ragwort control. *Research progress report Western Society of Weed Science*, **1986**, 53-54.

Woodcook, J.W. (1936) Control of ragwort with "Atlacide" as compared with sodium chlorate. *New Zealand journal of agriculture*, **53**, 65.

10.2. References to Studies Excluded from this Systematic Review

All references viewed at both the title and abstract or at the full text filtering stages are available on request as an Endnote Library or Excel file.

10.3. Additional References

Bacon, J. (2004). Personal communication.

Defra (2003). Draft Code of Practice to Prevent and Control the Spread of Ragwort. Department for Environment, Food and Rural Affairs.

EN (2003). Information note - Common ragwort, *Senecio jacobaea*.

EN, (2003b) *The Herbicide Handook: Guidance on the use of herbicides on nature conservation sites*, Wetherby, West Yorkshire.

Goodman, G.T. & Gillham, M.E. (1954). Ecology of the Pembrookeshire islands II. Stokholm environment and vegetation. *Journal of Ecology*, **42**, pp 296-327.

Grimes, J.P., Hodgson, J.G., & Hunt, R. (1988). *Comparative Plant Ecology: a funtional approach to common British species* Unwin Hyman, London, U.K.

Harper, J.L. & Wood, W.A. (1957). Biological Flora of the British Isles: - *Senecio jacobaea* L. *Journal of Ecology*, **45**, 617-637.

Oates, M. (2004). Personal communication.

Simpson, N. (1993). A summary review of information on the autecology and control of six grassland weed species. Rep. No. 44, Peterborough.

Sutton, A.J., Abrams, K.R., Jones, D.R., Sheldon, T.A., & Song, F. (2000) *Methods for Meta-Analysis in Medical Research* John Wiley & Sons, Chichester.

Appendix 1. Quality Assessment Instrument to provide an estimate of bias surrounding extracted data.

Bias	Generic data quality features	Specific data quality features	Quality element	Quality score
Selection and Performance bias	Study Design	NA	Randomized controlled Trial	**80**
			Quasi-RCT (a trail applying a pseudo random allocation mechanism, e.g. date of planting)	**70**
			Controlled Trial	**60**
			Historical CT (data for the control arm comes from archives not from current experimental observation	**50**
			Site comparison	**40**
			Time Series	**30**
			Interrupted time series	**20**
			Questionnaire	**10**
			Expert Opinion	**10**
	Baseline comparison (heterogeneity between treatment and control arms with respect to defined confounding factors before treatment)	Factors: Size of experimental area	Treatment and control arms homogenous	**1**
			Treatment and control arms not comparable with respect to confounding factors OR insufficient information	**0**
		Habitat type,	Treatment and control arms homogenous	**1**
			Treatment and control arms not comparable with respect to confounding factors OR insufficient information	**0**
		Location/Geographical Area	Treatment and control arms homogenous	**1**
			Treatment and control arms not comparable with respect to confounding factors OR insufficient information	**0**
		Altitude.	Treatment and control arms homogenous	**1**
			Treatment and control arms not comparable with respect to confounding factors OR insufficient information	**0**
		Plant age at time of treatment	Treatment and control arms homogenous	**1**

	Baseline comparison (cont.)		Treatment and control arms not comparable with respect to confounding factors OR insufficient information	**0**
		Soil Type	Treatment and control arms homogenous	**1**
			Treatment and control arms not comparable with respect to confounding factors OR insufficient information	**0**
	Intra treatment variation	Factors: Plant age at time of treatment	No heterogeneity within treatment and control arms	**1**
			Replicates within treatment and control arms not comparable	**0**
		Habitat type,	No heterogeneity within treatment and control arms	**1**
			Replicates within treatment and control arms not comparable	**0**
		Location,	No heterogeneity within treatment and control arms	**1**
			Replicates within treatment and control arms not comparable	**0**
		Altitude.	No heterogeneity within treatment and control arms	**1**
			Replicates within treatment and control arms not comparable	**0**
	Measurement of intervention and Co-interventions	Chemical application	Factor equal in treatment and control	**1**
			Factor not equal or unreported	**0**
Assessment bias	Measurement of outcome	Replication, parameter of abundance (accuracy)	Well replicated objective parameter of abundance used (>2 replications)	**4**
			Replicated objective parameter of abundance used (1 – 2 replications)	**2**
			Unreplicated observations or subjective parameter of abundance used	**0**
Attrition bias	Assessment of treatment effect on sample number	NA	No losses to follow up	**2**
			Minor (<20%) losses to follow up	**1**
			Major (>20%) losses to follow up	**0**

Appendix 2. Study Characteristics Tables for each study accepted at full text.

Study 1	**Appleby, A.P. (1979)**			
Methods	Brief report (1 page) of a site comparison based on Asulam application against a single control of no treatment.			
Population	Size of experimental area:	Unknown		
	Habitat:	Agricultural fields planted with alfalfa		
	Location:	Oregon, USA		
	Altitude:	Unknown		
	Plant age at time of treatment:	Unknown		
	Soil type:	Unknown		
Intervention & Comparator	No details of methods of application. Asulam was applied at a combined dosage of 2.57kg ai/ha against a replicate of only one control.			
Outcomes used within systematic review meta-analysis		**Ragwort control (%)**		
		Mean	**n**	**s.d.**
	Treatment (Asulam)	**86.66**	**3**	**20.50**
	Control	**0**	**1**	**0**
Study design	Site comparison **40pts**			
Baseline comparison	Size of sites, altitude, plant age & soil types all unknown. The habitat and location were both similar **2pts**			
Intra treatment variation	Habitat and location were both similar other factors unknown. **2pts**			
Measurement of intervention and co-interventions	Intervention measure unequal and combination of three different doses for mean control. No statement of any co-interventions on sites. **0pts**			
Replication & parameter of abundance	Replication is uneven with 3 in the treatment arm and 1 in the control arm. **2pts**			
Attrition bias	No losses to follow-up **2pts**			
Data Quality Score Total	**48pts**			
Other data presented in study however **not used** in review meta-analysis	Experiment 1 Ragwort control with 2.2kg/ha of 2,4-D ester applied on six different dates in spring (time series data with no control – from table 1 of study).			
Associated Outcomes	Date treatment applied	Ragwort control (%)		
	Feb 21st	72		
	March 23rd	93		
	April 20th	98		
	May 4th	98		
	May 15th	73		
	May 31st	52		
Other data presented in study however **not used** in review meta-analysis	Experiment 2 Ragwort control with 2.2kg/ha or 3.4kg/ha of 2,4-D ester applied in April (time series data with no control and combination of dosages – from table 2 of study).			
Associated Outcomes	Year	No. of locations	Avg. % control	
	1972	2	100	
	1973	5	99	
	1974	13	98	
Other notes	Data included in the systematic review analysis is based solely on table 3 in the original study, by combining the 3 treatment doses (1.1, 2.2 & 4.4kg a.i./ha) to get mean dosage (2.57kg a.i./ha). The study quality (site comparison) is based on worse-case scenario as the description of the experimental design was vague			

<table>
<tr><th>Study 2</th><th colspan="4">Black, W.N. (1976)</th></tr>
<tr><td>Methods</td><td colspan="4">A randomized block design with all experiments having replicates for at minimum the treatment arm.</td></tr>
<tr><td rowspan="6">Population</td><td>Size of experimental area:</td><td colspan="3">Varied with experiment, however consistent size to plots within each experimental arm.</td></tr>
<tr><td>Habitat:</td><td colspan="3">Rotationally grazed pasture. Sward consisted of Kentucky bluegrass (Poa pratensis), timothy (Phleum pratense) bentgrass (Agrostis tenuis) and white clover (Trifolium repens).</td></tr>
<tr><td>Location:</td><td colspan="3">Prince Edward Island, Charlottetown, Canada.</td></tr>
<tr><td>Altitude:</td><td colspan="3">Unknown.</td></tr>
<tr><td>Plant age at time of treatment:</td><td colspan="3">Ragwort plants varied from seedling to flowering stage, numbering 4-41 plants/m^2.</td></tr>
<tr><td>Soil type:</td><td colspan="3">(Canadian) Charlottetown light sandy loam.</td></tr>
<tr><td>Intervention & Comparator</td><td colspan="4">Effect of Herbicide Rates (Datasets A & B)
The effects of the rates of 2,4-D ester and 2,4-DB [4-(2,4-dichlorophenoxy) butyric acid] combined dosage was used to give 2.57 kg ai/ha in water at 275 litres/ha, pressure of 276 kPa. All plots initially sprayed 24th June 1959 then repeated 15th June & 27th September 1960. There were 3 replicates for each treatment and 1 for the control. Presented in the original study as experiment 2 (table 1).</td></tr>
<tr><td rowspan="5">Outcomes used within systematic review meta-analysis</td><td></td><td></td><td colspan="2">% ragwort plants dead</td></tr>
<tr><td></td><td>kg a.i./ha</td><td>Dataset A (1959)</td><td>Dataset B (1960)</td></tr>
<tr><td>2,4-D ester</td><td>2.57</td><td>90.33</td><td>99.13</td></tr>
<tr><td>2,4-DB ester</td><td>2.57</td><td>58.37</td><td>88.33</td></tr>
<tr><td>Control</td><td>0</td><td>31.40</td><td>42.50</td></tr>
<tr><td>Intervention & Comparator</td><td colspan="4">Effect of Time of Application on Ragwort Control (Dataset C)
2,4-D ester applied at 2.2 kg/ha in water at 275 litres/ha applied in June, June & September or September. Trials conducted on different plot areas each year so no accumulation of herbicide occurred. The trial was undertaken for 3 separate years 1959, 60 & 62 the average was taken. Both the treatment & control had 3 replicates. Presented in the original study as experiment 3 (table 2).</td></tr>
<tr><td rowspan="5">Outcomes used within systematic review meta-analysis</td><td colspan="3">Dataset C</td></tr>
<tr><td></td><td>kg/ha</td><td>% ragwort plants dead</td></tr>
<tr><td>June</td><td>2.2</td><td>84.2</td></tr>
<tr><td>June & Sept</td><td>2.2 at each spray</td><td>100.0</td></tr>
<tr><td>Sept</td><td>2.2</td><td>68.0</td></tr>
<tr><td>Control</td><td>0</td><td>30.2</td></tr>
<tr><td>Intervention & Comparator</td><td colspan="4">The Effects of Different Herbicides on Ragwort (Dataset D)
Nine herbicides were tested for their effectiveness in the control of ragwort. The trails were conducted on different plots to prevent herbicide build-up over the years of 1963, 1964, 1965 and 1967. Herbicides screened included CMPP (±) 2-[(4-chloro-l-tolyl) oxy) propionic acid], CP 1815 (chlorinated benzoic & cresoxy-acetic acid), 2,3,6-TBA (dimethylamine salt of 2,3,6-Trichlorobenzoic acid), 2,4-D acid [weedone638, emulsifiable concentrate-(2,4-dichlorophenoxy) acetic acid], fenoprop [2-2,4,5-trichorophenoxy) proponic acid], MCPB [4-((4-chloro-o-tolyl) oxy) butyric acid], 2,4-DB, MCP and 2,4-D ester. Single sprays were applied with the results of the different spray concentrations combined. Each herbicide was applied in water at 337 litres/ha and at a pressure of 345kPa. Treatments applied between mid-June and mid-July. Recording weed density was undertaken immediately before spraying and 6-8 week follow-up. At</td></tr>
</table>

<table>
<tr><td></td><td colspan="5">4-5 week intervals, weed counts were made to determine invasion of new saplings. Counts made on two fixed areas of 0.8m^2 chosen at random in each 2.44x6.10m plot.</td></tr>
<tr><td rowspan="11">Outcomes used within systematic review meta-analysis</td><td colspan="5">Dataset D</td></tr>
<tr><td></td><td colspan="2">Kg a.i./ha</td><td colspan="2">% ragwort plants dead</td></tr>
<tr><td>CMPP</td><td colspan="2">2.6</td><td colspan="2">83.87</td></tr>
<tr><td>CP1815</td><td colspan="2">2.6</td><td colspan="2">79.17</td></tr>
<tr><td>2,4-D ester</td><td colspan="2">1.56</td><td colspan="2">87.50</td></tr>
<tr><td>2,3,6-TBA</td><td colspan="2">2.6</td><td colspan="2">85.93</td></tr>
<tr><td>2,4-D acid</td><td colspan="2">2.8</td><td colspan="2">86.57</td></tr>
<tr><td>Fenoprop</td><td colspan="2">2.6</td><td colspan="2">75.53</td></tr>
<tr><td>MCP</td><td colspan="2">1.07</td><td colspan="2">55.77</td></tr>
<tr><td>2,4-DB</td><td colspan="2">1.53</td><td colspan="2">53.70</td></tr>
<tr><td>MCPB</td><td colspan="2">1.67</td><td colspan="2">47.27</td></tr>
<tr><td>Control</td><td colspan="2">0.0</td><td colspan="2">5.20</td></tr>
<tr><td>Study design</td><td colspan="5">Randomized blocks (RCT) 80pts</td></tr>
<tr><td>Baseline comparison</td><td colspan="5">Except for altitude, all factors are known and suitably similar for comparison. 5pts</td></tr>
<tr><td>Intra treatment variation</td><td colspan="5">Again except for altitude, all factors are known and suitably similar for comparison. 3pts</td></tr>
<tr><td>Measurement of intervention and co-interventions</td><td colspan="5">Rotational grazed pasture with annual early spring broadcast spray treatments of N 47kg/ha, P 41kg/ha & K 78kg/ha, supplemented by 47 kg N/ha in mid-July and again in mid-August. Manure also applied at 22 t/ha every 3 years. The forage dry matter was maintained at 11 t/ha during the study period. 2pts</td></tr>
<tr><td>Replication & parameter of abundance</td><td colspan="5">All experiments had 3 replicates, with the exception of the herbicide evaluation studies (1963-64-65-67) which had 2 replicates. 4pts</td></tr>
<tr><td>Attrition bias</td><td colspan="5">No losses to follow-up. 2pts</td></tr>
<tr><td rowspan="2">Data Quality Score Total</td><td>Dataset</td><td>A</td><td>B</td><td>C</td><td>D</td></tr>
<tr><td>Pts</td><td>96</td><td>96</td><td>96</td><td>96</td></tr>
<tr><td>Other data presented in study however not used in review meta-analysis</td><td colspan="5">2,4-D ester [(2,4-dichlorophenoxy) acetic acid] and MCP amine [((4-chloro-o-tolyl)oxy) acetic acid] were applied as single treatments 12th July 1956, then repeat treatments on the same plot on 15th July and 17th October 1957 and again on the 4th August 1958. Rates of application 0, 0.28, 0.56, 1.12 kg/ha in water at 144 litres/ha at a pressure of 276 kPa. (experiment 1 – preliminary investigation)</td></tr>
<tr><td rowspan="3">Associated Outcomes</td><td colspan="2">Max lvls of treatment type</td><td>Average % Ragwort control</td><td colspan="2">White clover damage</td></tr>
<tr><td colspan="2">2,4-D</td><td>96.2</td><td colspan="2">Yes (re-established within weeks)</td></tr>
<tr><td colspan="2">MCP</td><td>65.5</td><td colspan="2">Yes (re-established within weeks)</td></tr>
<tr><td>Other notes</td><td colspan="5">High rate applications of the herbicide (4.5kg a.i./ha) were observed to caused severe burning to grasses and killed white clover and red clover (Trifolium pratense).
2,4-DB, MCPB and MCP at all rates failed to give adequate control of ragwort but did not affect white clover or grasses adversely.
By delaying spraying until September allowed older plants to flower and set seed therefore serving as centres of new infestation.
Spraying during June-July (during the vigorous growing stages) facilitated translocation of herbicide hormones from the foliage to the root system which was eventually killed.
The use of high-volume sprays resulted in better leaf coverage than low volume sprays, rendering the herbicide more effective.
“Only by maintenance of high soil fertility and careful grazing management, so as to avoid the development of an open sward, was it possible to stimulate growth of the desired forage species to exclude ragwort.”</td></tr>
</table>

Study 3	Clay, D.V. & Dixon, F.L. (1998)					
Methods	A series of 5 control trials using different spray dates with standardised dose of 0.117kg ai/ha of Clopyralid on potted common ragwort (*S. jacobaea*).					
Population	Size of experimental area:			Pots – 15cm diameter each		
	Habitat:			Plants grown from seed sown in late May in a glasshouse. Moved outside for the experiment.		
	Location:			UK, Bristol area.		
	Altitude:			Unknown		
	Plant age at time of treatment:			3 months to 1 year.		
	Soil type:			Soil based compost		
Intervention & Comparator	The combination of 3 treatments = 0.117kg ai/ha of Clopyralid sprayed on different dates on different sets of potted plants compared to no treatment (0 for each date). The dosage was in water at 230 litres/ha and 210 kPa pressure sprayed using a track sprayer fitted with an 80015E Flat Fan nozzle. The controls are independent rounded to the nearest whole number. The shoot fresh weight being recorded in July 1996. The stage of growth of the plants varied at each date – at first application the plants generally had large leafy rosettes. At time of 2nd date – stem extension and senescing. 3rd date – established prostate rosettes present. 4th date – stem extension. Final date – further stem extension (1 year old plants).					
Outcomes used within systematic review meta-analysis				**Shoot weight (g/pot)**		
	Dataset	**Date**		**0.117kg ai/ha**	**Control**	
	A	**17/08/95**		**267.67**	**340**	
	B	**26/09/95**		**134.50**	**340**	
	C	**25/04/96**		**143.00**	**340**	
	D	**15/05/96**		**293.67**	**340**	
	E	**04/06/96**		**76.33**	**340**	
Study design	Control trial					**60pts**
Baseline comparison	Size of pots, plant age, soil type, habitat and location all similar, while altitude is unknown.					**5pts**
Intra treatment variation	Plant age at time of treatment, habitat and location all similar again altitude is unknown.					**3pts**
Measurement of intervention and co-interventions	Intervention measures equal with same number of replicates in each arm of the study. No co-intervention as plants in pots with similar conditions (e.g. watering and weather)					**2pts**
Replication & parameter of abundance	Replication is uneven between arms, however 3 replicates for each treatment and 1 for the control					**4pts**
Attrition bias	No losses to follow-up					**2pts**
Data Quality Score Total	**Dataset**	**A**	**B**	**C**	**D**	**E**
	Pts	**76**	**76**	**76**	**76**	**76**
Other data presented in study however **not used** in review meta-analysis	Plant Health scores for the data above. These were assessed for growth and damage using a score of 0-7; (0 = dead, 4 = 50% reduction in growth and 7 = as healthiest untreated).					
Associated Outcomes		Plant Health (score 0-7)				
		0.05	0.1	0.2	Control	
	17/08/95	5.7	4.5	3.8	7.0	
	26/09/95	4.7	4.0	3.8	6.0	
	25/04/96	4.7	4.3	3.8	6.3	
	15/05/96	4.5	4.0	3.5	7.0	
	04/06/96	4.7	4.0	3.8	7.0	

Study 4	Coles, P.G. (1967)		
Methods	A series of 6 control trials using different spray dates and doses of Picloram and 2,4-D ester to control common ragwort on a variety of different soils. Both broadcast and spot spray application was studied. Measurements are on a subjective 0-10 numerical scale using 2 or more independent observers. (0 = no effect; 10 = complete control).		
Population	Size of experimental area:	Plots of 20.16m^2	
	Habitat:	Varies, see individual trials.	
	Location:	New Zealand, however sites vary see individual trials.	
	Altitude:	Unknown	
	Plant age at time of treatment:	Varies, see individual trials.	
	Soil type:	Varies, see individual trials.	
Intervention & Comparator	**Trial 1: November 1965 Broadcast application (Dataset A)** The ragwort plants were in an advanced "cabbage" to flower bud stage, ranging in height from 30-107cm. Both 2,4-D ester and a combination of Picloram and 2,4-D were sprayed during November 1965, using an Oxford Precision Sprayer at an application rate of 58.1 l/ha at 3mph. Follow-up time from treatment was 11 weeks. Soil type was a free-draining brown loam.		
Outcomes used within systematic review meta-analysis	**Dataset A**		
			Follow-up time
	Treatment	**Dose ai/ha**	**11 weeks**
	2,4-D ester only	**0.24kg**	**6.8**
	Picloram/2,4-D	**0.02/0.09kg**	**7.6**
	Control	**0**	**0**
Intervention & Comparator	**Trial 2: May 1966 Broadcast application (Dataset B)** Late autumn application, ragwort plants were in early "cabbage" stage, prior to the appearance of flower stalks, ranging in height from 7 to 20 cm. Same application equipment and rate as above. Soil type was a light pumice ash.		
Outcomes used within systematic review meta-analysis	**Dataset B**		
			Follow-up time
	Treatment	**Dose ai/ha**	**32 weeks**
	2,4-D ester only	**0.24kg**	**8.0**
	Picloram/2,4-D	**0.02/0.09kg**	**9.0**
	Control	**0**	**0**
Intervention & Comparator	**Trial 4: October 1965 Spot spray treatment (Dataset C)** Spot spray treatment applying about 568.75 litres a wetted hectare was made to actively growing ragwort plants from seedling to advanced "cabbage" growth stage. The herbicides were applied with a hand wand using a standard engine-driven pump unit at 14.3kg/cm^2. The soil type = free-draining brown loam.		
Outcomes used within systematic review meta-analysis	**Dataset C**		
			Follow-up time
	Treatment	**Dose kg/ litre**	**12 weeks**
	2,4-D ester only	**0.06**	**10**
	Picloram/2,4-D	**0.005/0.017**	**9.75**
	Control	**0**	**0**

<table>
<tr><td>Intervention & Comparator</td><td colspan="5">Trail 5: Dec. 1966 Broadcast Picloram granules (Dataset D)
Ragwort plants were in vegetative to early bud stage, ranging in height from 10 to 72cm. The picloram granules were based on an absorbent attapulgite clay core. The soil type was egmont volcanic ash. The follow-up time was 3 months.</td></tr>
<tr><td rowspan="6">Outcomes used within systematic review meta-analysis</td><td colspan="5">Dataset D</td></tr>
<tr><td>Treatment</td><td>Dose kg ai/ha</td><td>Top kill</td><td>Root kill</td><td>Combined data used</td></tr>
<tr><td>Picloram</td><td>0.14</td><td>5.8</td><td>5.5</td><td>5.65</td></tr>
<tr><td>Picloram</td><td>0.27</td><td>9.6</td><td>8.9</td><td>9.25</td></tr>
<tr><td>Picloram</td><td>0.54</td><td>9.6</td><td>9.5</td><td>9.55</td></tr>
<tr><td>Control</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Study design</td><td colspan="5">Control trial 60pts</td></tr>
<tr><td>Baseline comparison</td><td colspan="5">Size of plots, plant age, soil type, habitat and location all similar, while altitude is unknown. 5pts</td></tr>
<tr><td>Intra treatment variation</td><td colspan="5">Plant age at time of treatment, habitat and location all similar again altitude is unknown. 3pts</td></tr>
<tr><td>Measurement of intervention and co-interventions</td><td colspan="5">Intervention measures equal with same number of replicates in each arm of the study. No co-intervention undertaken. 2pts</td></tr>
<tr><td>Replication & parameter of abundance</td><td colspan="5">Replication is only one between 2,4-D ester only and control, Picloram has 3 replicates. However subjective parameter used to measure. 0pts</td></tr>
<tr><td>Attrition bias</td><td colspan="5">No losses to follow-up. 2pts</td></tr>
<tr><td rowspan="2">Data Quality Score Total</td><td>Dataset</td><td>A</td><td>B</td><td>C</td><td>D</td></tr>
<tr><td>pts</td><td>72</td><td>72</td><td>72</td><td>72</td></tr>
<tr><td>Other data presented in study however not used in review meta-analysis</td><td colspan="5">Trial 6: January 1967 Seed Viability
Assessment of the viability of seed harvested from ragwort sprayed in full flower. Abnormal seeds died a few days after germination.</td></tr>
<tr><td rowspan="8">Associated Outcomes</td><td>Treatment</td><td colspan="2">Dose kg ai/ha</td><td>% Germination</td><td>% Seed Abnormal</td></tr>
<tr><td>2,4-D ester</td><td colspan="2">0.36</td><td>20</td><td>17</td></tr>
<tr><td>Picloram/2,4-D</td><td colspan="2">0.01/0.05</td><td>47</td><td>12</td></tr>
<tr><td>Picloram/2,4-D</td><td colspan="2">0.02/0.09</td><td>31</td><td>12</td></tr>
<tr><td>Picloram/2,4-D</td><td colspan="2">0.03/0.14</td><td>26</td><td>10</td></tr>
<tr><td>Picloram/2,4-D</td><td colspan="2">0.05/0.18</td><td>9</td><td>27</td></tr>
<tr><td>Untreated Control</td><td colspan="2">0</td><td>33</td><td>16</td></tr>
<tr><td></td><td colspan="5"></td></tr>
<tr><td>Other notes</td><td colspan="5">Trial 3 showed no control of ragwort due to heavy rain within 1 hour of application. This would have reduced uptake of the chemicals to a sub-lethal level, as the spray droplets would have not even dried on the foliage. No data was presented.
Trial 4 (dataset C) after 12 weeks seedling regrowth was present in the 2,4-D ester plot.</td></tr>
</table>

<table>
<tr><th>Study 5</th><th colspan="7">Courtney, A. D. & Johnston, R. (1976)</th></tr>
<tr><td>Methods</td><td colspan="7">A series of control trials using different spray dates and 5 different herbicides.</td></tr>
<tr><td rowspan="6">Population</td><td colspan="4">Size of experimental area:</td><td colspan="3">Varies with each experiment, see descriptions below.</td></tr>
<tr><td colspan="4">Habitat:</td><td colspan="3">Grazing pasture</td></tr>
<tr><td colspan="4">Location:</td><td colspan="3">Northern Ireland</td></tr>
<tr><td colspan="4">Altitude:</td><td colspan="3">Unknown</td></tr>
<tr><td colspan="4">Plant age at time of treatment:</td><td colspan="3">Varies with each experiment, see descriptions below.</td></tr>
<tr><td colspan="4">Soil type:</td><td colspan="3">Varies with each experiment, see descriptions below.</td></tr>
<tr><td>Intervention & Comparator</td><td colspan="7">Experiment 1 – County Down, N. Ireland (Datasets A-E)
Conducted on a coastal site at Portavogie, County Down, N. Ireland in a 0.81 hectare (2 acre) field, which was subjected to a continuous intensive cattle grazing throughout the year. There had been a history of stock fatalities on this site. All treatments were applied in 1973. The plots were arranged in 10m stripes, per date of application, in a regular progression across the field. The 10m strip was divided into 4 blocks within which there where 8 individual plots of 2m x 10m. Each area was fenced off for a period of a month. The herbicides used were MCPA, 2,4-D amine, 2,4-D ester, Dicamba mecoprop, Mecoprop and Dichlorprop. They were applied with an Oxford precision sprayer with a 4 ‘00’ ceramic fan jets at 45.2cm spacing and a pressure of 2 bar, giving an output of 225 litres/ha of water.</td></tr>
<tr><td rowspan="11">Outcomes used within systematic review meta-analysis</td><td colspan="7">Measurements are in Ragwort plants per m^2 (1973)</td></tr>
<tr><td colspan="2">Dataset</td><td>A</td><td>B</td><td>C</td><td>D</td><td>E</td></tr>
<tr><td colspan="2">Spray Date</td><td>May 11</td><td>June 12</td><td>July 17</td><td>Aug 13</td><td>Oct 2</td></tr>
<tr><td colspan="2">Assessment Date</td><td rowspan="2">June 12</td><td rowspan="2">July 17</td><td rowspan="2">Aug 13</td><td rowspan="2">Oct 2</td><td rowspan="2">Nov 1</td></tr>
<tr><td>Treatment</td><td>Dose</td></tr>
<tr><td>MCPA</td><td>2.24</td><td>0.57</td><td>2.20</td><td>2.03</td><td>0.30</td><td>1.94</td></tr>
<tr><td>2,4-D amine</td><td>2.24</td><td>0.80</td><td>5.51</td><td>1.01</td><td>0.59</td><td>2.59</td></tr>
<tr><td>2,4-D ester</td><td>1.68</td><td>0.23</td><td>5.51</td><td>2.03</td><td>0.00</td><td>3.45</td></tr>
<tr><td>Dicamba mecoprop</td><td>0.56</td><td>0.00</td><td>2.48</td><td>1.01</td><td>1.18</td><td>1.73</td></tr>
<tr><td>Mecoprop</td><td>3.57</td><td>0.46</td><td>4.41</td><td>2.03</td><td>0.59</td><td>1.29</td></tr>
<tr><td>Dichlorprop</td><td>2.80</td><td>1.15</td><td>3.59</td><td>0.00</td><td>0.49</td><td>6.05</td></tr>
<tr><td>Control</td><td>0</td><td>5.40</td><td>5.10</td><td>4.30</td><td>4.00</td><td>6.80</td></tr>
<tr><td>Intervention & Comparator</td><td colspan="7">Experiment 2 – Co. Down & Co. Antrim, N. Ireland
The herbicide treatments – MCPA salt, 2,4-D ester and Dicamba/Mecoprop/MCPA were applied at 2 sites – Ballyesborough, Co. Down and Glenavy, Co. Antrim. The plot sizes were 6 x 25m and application was made with a Land Rover mounted sprayer at a volume of 220 litres/ha. A combination of the % control for flowering plants and seedlings were calculated for the longest time series.</td></tr>
</table>

Outcomes used within systematic review meta-analysis	**Measurements are in Ragwort plants per m^2**							
				Application Date				
	Dataset			**F**		**G**		
		Treatment	**Dose Kg ai/ha**	**April 1975**		**July 1975**		
	Site A assessed July 1975	**MCPA**	**2.24**	**1.98**		**-**		
		2,4-D	**1.68**	**0**		**-**		
		DMM	**2.56**	**0**		**-**		
		Control	**0**	**9.8**		**-**		
	Site A assessed July 1976	**MCPA**	**2.24**	**-**		**9.615**		
		2,4-D	**1.68**	**-**		**8.79**		
		DMM	**2.56**	**-**		**10.935**		
		Control	**0**	**-**		**13.75**		
	Site B assessed July 1976	**MCPA**	**2.24**	**0.0525**		**-**		
		2,4-D	**1.68**	**0.0025**		**-**		
		DMM	**2.56**	**0**		**-**		
		Control	**0**	**0.115**		**-**		
Study design	Control trial **60pts**							
Baseline comparison	Size of plots, plant age, habitat, soil type and location all similar, while altitude is unknown. **5pts**							
Intra treatment variation	Plant age at time of treatment, habitat and location all similar again altitude is unknown. **3pts**							
Measurement of intervention and co-interventions	Intervention measures equal with same number of replicates in each arm of the study. Co-intervention/prior management of grazing recorded and similar. **2pts**							
Replication & parameter of abundance	Replication is only 1 in each of the treatment arms, however 2 replicates for the control. **2pts**							
Attrition bias	No losses to follow-up **2pts**							
Data Quality Score	**Dataset**	**A**	**B**	**C**	**D**	**E**	**F**	**G**
Total	**pts**	**74**	**74**	**74**	**74**	**74**	**74**	**74**
Other notes								

<table>
<tr><th>Study 6</th><th colspan="3">Dixon, F. L. & Clay, D. V. (2001)</th></tr>
<tr><td>Methods</td><td colspan="3">A series of field based control trials. The 1st trial includes conventional spraying of clopyralid, 2,4-D, triclopyr, fluroxypyr/triclopyr and glyphosate and also weed wiper applications of glyphosate and clopyralid. The 3rd trial includes citronella-oil, clopyralid and 2,4-D.</td></tr>
<tr><td rowspan="6">Population</td><td colspan="2">Size of experimental area:</td><td>Varies with each experiment, see descriptions below.</td></tr>
<tr><td colspan="2">Habitat:</td><td>Uncropped land.</td></tr>
<tr><td colspan="2">Location:</td><td>Failand, nr. Bristol, U.K.</td></tr>
<tr><td colspan="2">Altitude:</td><td>Unknown</td></tr>
<tr><td colspan="2">Plant age at time of treatment:</td><td>Varies with each experiment, see descriptions below.</td></tr>
<tr><td colspan="2">Soil type:</td><td>Silty loam soil.</td></tr>
<tr><td>Intervention & Comparator</td><td colspan="3">Experiment 1 in the paper (Dataset A)
All ragwort plants were raised from seed sown on the same date in trays of peat-based compost and transplanted 1 per 9cm pot in early September. Four months later planted out into 1 x 3m plots, with 12 plants a plot, 0.5m spacing in 2 rows. Treatments of clopyralid (Dow AgroSciences), 2,4-D amine (Agricorn D; 50% SL: Farmers Crop Chemicals Ltd), triclopyr (Garlon 4; 48% EC: Dow AgroSciences), fluroxypyr/triclopyr (Evade; 2:6% EC: Dow AgroSciences) and glyphosate (Roundup Pro Biactive; 36% SL: Monsanto (UK) Ltd) were sprayed using an Oxford Precision Sprayer (OPS) fitted with a 11002 flat fan nozzle at a pressure of 98 kPa and spray volume of 250 liters/ha. Weed wiper (ww) applications of glyphosate (33.5% product solution)and clopyralid (50% product solution) were made using a hand-held, rope, wick applicator (Weed Wick Mini). Follow-up was done 3 months after application.</td></tr>
<tr><td>Outcomes used within systematic review meta-analysis</td><td colspan="3">Dataset A
<table>
<tr><th>Treatment</th><th>Dose kg ai/ha</th><th>Cover of Ragwort (%)</th></tr>
<tr><td>Clopyralid</td><td>0.2</td><td>45</td></tr>
<tr><td>2,4-D amine</td><td>2.3</td><td>56.25</td></tr>
<tr><td>Triclopyr</td><td>1.92</td><td>31.25</td></tr>
<tr><td>Fluroxypr + triclopyr</td><td>0.4</td><td>70</td></tr>
<tr><td>Glyphosate</td><td>1.44</td><td>33.75</td></tr>
<tr><td>Glyphosate (ww)</td><td>33.5% product solution</td><td>0</td></tr>
<tr><td>Clopyralid (ww)</td><td>50% product solution</td><td>0</td></tr>
<tr><td>Control</td><td>0</td><td>82.5</td></tr>
</table></td></tr>
<tr><td>Intervention & Comparator</td><td colspan="3">Experiment 3 (in the paper) Dataset B-D
Small plots of 1 x 2m, laid out on a natural population of common ragwort on an uncropped field. Herbicides in ready to use formulation of citronella oil (Barrier H; 22.9% EC: Barrier Biotech Ltd) at 1500 litres/ha, 2,4-D at 2.1 kg ai/ha and clopyralid at 0.2 kg ai/ha sprayed on 3 different dates. March spraying ragwort was small to large compact rosettes, April spray plants actively growing but not extended, May plant shoots were up to 35cm tall with no flower buds. Applications made with an OPS fitted with 2 11003 flat fan nozzles.</td></tr>
</table>

<table>
<tr><td rowspan="6">Outcomes used within systematic review meta-analysis</td><td colspan="5">Plant Health Scores (0-7) 0 = dead, 4 = 50% growth reduction & 7 = best untreated.</td></tr>
<tr><td>Treatment</td><td>Dose</td><td>March
B</td><td>April
C</td><td>May
D</td></tr>
<tr><td>Citronella</td><td>1500 litres/ha</td><td>5.0</td><td>5.0</td><td>7.0</td></tr>
<tr><td>2,4-D</td><td>2.1 kg ai/ha</td><td>3.3</td><td>2.3</td><td>3.0</td></tr>
<tr><td>Clopyralid</td><td>0.2 kg ai/ha</td><td>2.7</td><td>1.3</td><td>2.3</td></tr>
<tr><td>Control</td><td>0</td><td>7.0</td><td>7.0</td><td>7.0</td></tr>
<tr><td>Study design</td><td colspan="5">Control trial 60pts</td></tr>
<tr><td>Baseline comparison</td><td colspan="5">Size of plots, plant age, habitat, soil type and location all similar, while altitude is unknown. 5pts</td></tr>
<tr><td>Intra treatment variation</td><td colspan="5">Plant age at time of treatment, habitat and location all similar again altitude is unknown. 3pts</td></tr>
<tr><td>Measurement of intervention and co-interventions</td><td colspan="5">Intervention measures are even in each arm of the study. 2pts</td></tr>
<tr><td>Replication & parameter of abundance</td><td colspan="5">Replication is only 1 in each of the treatment arms, however 2 replicates for the control. 2pts</td></tr>
<tr><td>Attrition bias</td><td colspan="5">No losses to follow-up 2pts</td></tr>
<tr><td rowspan="2">Data Quality Score Total</td><td>Dataset</td><td colspan="2">A</td><td>B</td><td>C</td><td>D</td></tr>
<tr><td>Pts</td><td colspan="2">74</td><td>74</td><td>74</td><td>74</td></tr>
<tr><td>Other notes</td><td colspan="5">Experiment 1 – Weed wiper applications found to be very effective, with feasibility for application by hand-held equipment at the rosette stage only. A tractor-trailed version can be used on taller extending shoots.
In experiment 3 – The April & May clopyralid treatments prevented ragwort flowering.</td></tr>
</table>

Study 7	Dixon, F. L. & Clay, D. V. (In press) – (2004)				
Methods	A series of different application dates of 3 herbicides (Amidosulfuron, Pyridate & Tribenuron) against woodland weeds including common ragwort.				
Population	Size of experimental area:	15cm diameter pots			
	Habitat:	4 plants per pot			
	Location:	Long Ashton Research Station, Bristol, U.K.			
	Altitude:	Unknown			
	Plant age at time of treatment:	Documented – see below			
	Soil type:	Loam based compost			
Intervention & Comparator	**Experiment 4 (in the paper) – Susceptibility of weeds to contact herbicides at 3 growth stages – Datasets A-C** Ragwort was 1 of 4 weed species studied in this experiment. Seeds were sown in seed trays and lightly covered with sand in May 1996, transplanted to 15cm diameter pots containing loam based compost (no fertiliser) at end of May 1996. 4 plants per pot then grown outside from June. Herbicide treatments were Amidosulfuron (Eagle;75% w/wg; AgrEvo UK Crop Protection Ltd), Pyridate (Lentagran 45 WP; 45% w/w wp; Ciba Agriculture) & Tribenuron-methyl (Quantum; 50% w/w tb; Du Pont (UK) Ltd). They were formulated at half dose levels to that which is recommended. Laboratory tractor sprayer with a Lurmark 80015E flat fan nozzle at 210kPa and spray volume of 200 litres/ha was used. Sprayed at 3 different growth stages – plants kept under cover fro 24hr after spraying and then set outside in 4 randomised blocks on capillary matting. Plant growth stages as follows – June 10th 1-2 leaves, 15-25mm diameter. June 20th 3-4 pairs of leaves, prostrate 40-65mm diameter. July 15th 9-14 leaves, stolons 1-4cm				
Outcomes used within systematic review meta-analysis	**Plant Health Scores (0-7) 0 = dead, 4 = 50% growth reduction & 7 = best untreated.**				
	Dataset		**A**	**B**	**C**
	Treatment	**Dose Kg ai/ha**	**June 10**	**June 20**	**July 15**
	Amidosulfuron	**0.015**	**1.0**	**2.0**	**5.8**
	Pyridate	**0.450**	**1.3**	**3.0**	**7.0**
	Tribenuron	**0.0075**	**1.0**	**2.0**	**4.8**
	Control	**0**	**7**	**6.9**	**6.9**
Study design	Randomised control trail (RCT) **80pts**				
Baseline comparison	Size of pots, plant age, habitat, soil type and location all similar, while altitude is unknown. **5pts**				
Intra treatment variation	Plant age at time of treatment, habitat and location all similar again altitude is unknown. **3pts**				
Measurement of intervention and co-interventions	Intervention measures are even in each arm of the study. **2pts**				
Replication & parameter of abundance	Only 1 replicate per arm of the experiment. Subjective measure of abundance. **0pts**				
Attrition bias	No losses to follow-up. **2pts**				
Data Quality Score Total	**Dataset**	**A**	**B**	**C**	
	Pts	**92**	**92**	**92**	
Other data presented in study however **not used** in review analysis	Experiments on the effects of herbicide applied pre & post-emergence on shoot weight 6-8 weeks later were presented – however only in graph form so the data could not be used.				
Other notes	Pyridate treatment on the 15th July did not affect the growth of the ragwort. In the long-term (as experiment was only a 2 week follow-up) there were few effective treatments.				

Study 8	Eadie, I. M. & Robinson, B. D. (1953)		
Methods	A Randomised control trial (RCT) in Australia looking at 4 hormone-type herbicides (2,4-D, MCPA, 2,4-D/2,4,5-T mix & 2,4,5-T Butyl) for the control of common ragwort.		
Population	Size of experimental area:	40.23 x 2.51m plots.	
	Habitat:	Unkept land.	
	Location:	Australia, nr Foster.	
	Altitude:	Unknown, but on a hill.	
	Plant age at time of treatment:	Seedling to rosette.	
	Soil type:	Red loamy clay.	
Intervention & Comparator	A knapsack sprayer with attached 1.2m hand boom applied 72.8 litres/ha. Through 4 flat fan monarch-type nozzles when walking at 7m a minute. The operator walked the plots twice to deliver required volume of treatment. The mean (0.42 kg ai/ha) of 3 different treatment rates (0.18 kg ai/ha, 0.36 kg ai/ha & 0.72 kg ai/ha) was taken. The treatments were replicated 4 times in the study. Each rate of application was randomised within the treatment and each treatment was randomised within the four replicates. As experiment was on a hill the replicates were in pairs, 1 pair being on either side of the ridge which ran E-W. No rain fell within 48hr of treatment. November spray with January follow-up.		
Outcomes used within systematic review meta-analysis	**Treatment**	**Dose (kg ai/ha)**	**% Ragwort kill**
	2,4-D	**0.42**	**75**
	MCPA	**0.42**	**52**
	2,4-D/2,4,5-T mix	**0.42**	**65**
	2,4,5-T Butyl	**0.42**	**13**
	Control	**0**	**-17.2**
Study design	Randomised control trail (RCT) **80pts**		
Baseline comparison	Size of plots, plant age, habitat, soil type and location all similar, altitude is also known and uniform with the experimental design. **6pts**		
Intra treatment variation	Plant age at time of treatment, habitat, location and altitude are all similar. **4pts**		
Measurement of intervention and co-interventions	Intervention measures are even in each arm of the study. **2pts**		
Replication & parameter of abundance	Good replication and % kill parameter of abundance used. **4pts**		
Attrition bias	No losses to follow-up. **2pts**		
Data Quality Score Total	**98pts**		
Other notes	2,4,5-T Butyl is listed at time of publication to be a more expensive chemical than the others in this trial due to this point and the poor control of ragwort they do not recommend its usage in mixture or stand alone. A follow-up 18 months after the trial showed that there had been seedling regrowth and therefore recommended an additional treatment would be required. Ragwort plants treated after starting to run, prior to flowering continued to flower and set seed even while showing damage.		

Study 9	Forbes, J. C. (1977)						
Methods	A randomised control trial (RCT) of 4 herbicides (MCPA, 2,4-D, Asulam & 2,4-D/Asulam mix) for the control of marsh ragwort (*S. aquaticus*).						
Population	Size of experimental area:	20 x 6m plots					
	Habitat:	Ley grassland					
	Location:	U.K. Orkney Isle					
	Altitude:	Unknown					
	Plant age at time of treatment:	Ages of plant similar in each experiment, two generations of marsh ragwort present due to its biennial nature.					
	Soil type:	Unknown					
Intervention & Comparator	A factorial experiment with random layout at 3 sites on mainland Orkney. Marsh ragwort density of 1.5-2 plants/m^2. Herbicides delivered with a knapsack sprayer at approx. 225 l/ha of water were 4-chloro-2-methylphenoxyacetic acid (MCPA) salt, 2,4-dichlorophenoxyacetic acid (2,4-D) ester, methyl-N-(4 aminobenzenesulphonyl)-carbonate (Asulam) & 2,4-D/Asulam mix. Doseages in table below are in kg ai/ha. The follow-up in August are flowering ragwort plants, while in April they are rosettes.						
Outcomes used within systematic review meta-analysis	**Results are in N°. of plants per plot**						
		Dataset	**A**	**B**	**C**		
	Treatment April 1975	**Dose**	**August 1975**	**April 1976**	**August 1975**		
	MCPA	**1.68**	**83.1**	**17.4**	**12.6**		
	2,4-D	**1.4**	**32.7**	**12.1**	**4.15**		
	Asulam	**1.12**	**71.3**	**53.7**	**27.0**		
	2,4-D/Asulam mix	**1.12/1.12**	**35.9**	**22.0**	**9.4**		
	Control	**0**	**178.2**	**147.9**	**77.0**		
		Dataset	**D**	**E**	**F**		
	Treatment May 1975	**Dose**	**August 1975**	**April 1976**	**August 1975**		
	MCPA	**1.68**	**23.4**	**17.8**	**3.8**		
	2,4-D	**1.4**	**12.7**	**4.0**	**0.4**		
	Asulam	**1.12**	**49.6**	**33.4**	**14.9**		
	2,4-D/Asulam mix	**1.12/1.12**	**13.3**	**2.0**	**-3.9**		
	Control	**0**	**178.2**	**147.9**	**77.0**		
Study design	Randomised control trail (RCT) **80pts**						
Baseline comparison	Size of plots, plant age, habitat and location all similar, Soil type and altitude are also unknown. **4pts**						
Intra treatment variation	Plant age at time of treatment, habitat & location are all similar. Altitude is unknown. **3pts**						
Measurement of intervention and co-interventions	Intervention measures are even in each arm of the study. **2pts**						
Replication & parameter of abundance	Good replication and plants per plot abundance used. **4pts**						
Attrition bias	No losses to follow-up. **2pts**						
Data Quality Score Total	**Dataset**	**A**	**B**	**C**	**D**	**E**	**F**
	Pts	**95**	**95**	**95**	**95**	**95**	**95**

Study 10	Forbes, J.C. (1978)					
Methods	A randomised control trial (RCT) testing 9 different herbicides for control of common ragwort					
Population	Size of experimental area:		20 x 6m plots.			
	Habitat:		Fields for either grazing or silage.			
	Location:		U.K. Moray, NE Scotland.			
	Altitude:		Unknown			
	Plant age at time of treatment:		Flowering Stems.			
	Soil type:		Unknown			
Intervention & Comparator	Herbicides were randomly allocated 20 x 6m plots, replicated twice per field, with a knapsack sprayer delivering about 225 l/ha of water. Herbicide treatments were: MCPA 2.25 kg ai/ha; MCPA 2.25 kg ai/ha + Actipron mineral oil 6.75 l/ha; 2,4-D amine 2.25 kg ai/ha; 2,4-D amine 2.25 kg ai/ha + mineral oil 6.75 l/ha; 2,4-D ester 1.67 kg ai/ha ULV formulation; 4-CPA ester 2.25 kg ai/ha; mecoprop 2.75 kg ai/ha; MCPA + mecoprop + dicamba (Razol) 6 l/ha; MCPA + mecoprop + Asulam (Graslam) 8.5 l/ha; 2,4,5-T + mecoprop + dicamba (Bandock) 6 l/ha.					
Outcomes used within systematic review meta-analysis			**Results in flowering stems/plot**			
	Spraying Time		**October 1976**		**May 1977**	
	Location	**Dataset**	**Control**	**Treatment**	**Control**	**Treatment**
	Rothes	**A**	**159**	**2**	**-**	**-**
	Lossiemouth	**B**	**372**	**4**	**-**	**-**
	Elgin	**C**	**-**	**-**	**254**	**6**
	Lossiemouth	**D**	**-**	**-**	**85**	**2**
Study design	Randomised control trail (RCT) **80pts**					
Baseline comparison	Size of plots, plant age, habitat and location all similar, Soil type and altitude are also unknown. **4pts**					
Intra treatment variation	Plant age at time of treatment, habitat & location are all similar. Altitude is unknown. **3pts**					
Measurement of intervention and co-interventions	Intervention measures are even in each arm of the study. No other interventions being undertaken on the sites. **2pts**					
Replication & parameter of abundance	Originally 2 replicates per field, the mean of all herbicides are taken and given as both % control and ragwort/plot. **4pts**					
Attrition bias	No losses to follow-up. **2pts**					
Data Quality Score Total	**Dataset**		**A**	**B**	**C**	**D**
	Pts		**95**	**95**	**95**	**95**
Other notes	There was no significant difference between herbicides, between sites. All treatments gave excellent control.					

<table>
<tr><th>Study 11</th><th colspan="4">Forbes, J. C., Kilgour, D. W. & Carnegie, H. M. (1980)</th></tr>
<tr><td>Methods</td><td colspan="4">A number of site comparisons with 4 herbicides (2,4-D; MCPA; dichlorprop & graslam) for control of common ragwort.</td></tr>
<tr><td rowspan="6">Population</td><td colspan="2">Size of experimental area:</td><td colspan="2">Varies – results recorded as plants per 100m^2.</td></tr>
<tr><td colspan="2">Habitat:</td><td colspan="2">Farm fields used for silage or lay.</td></tr>
<tr><td colspan="2">Location:</td><td colspan="2">U.K., Moray & Nairn & upper Speyside, Scotland.</td></tr>
<tr><td colspan="2">Altitude:</td><td colspan="2">Unknown</td></tr>
<tr><td colspan="2">Plant age at time of treatment:</td><td colspan="2">All similar ages.</td></tr>
<tr><td colspan="2">Soil type:</td><td colspan="2">Unknown</td></tr>
<tr><td>Intervention & Comparator</td><td colspan="4">Case Studies (Dataset A)
Thirty-five fields on 21 farms were to be controlled for common ragwort in spring 1979. 4 herbicides of: 2,4-D; MCPA; dichlorprop & graslam were used as treatments. Averages of each herbicide dosage and the mean of ragwort control is used as an assessment. 20% losses to follow-up due to ploughing of fields.</td></tr>
<tr><td rowspan="7">Outcomes used within systematic review meta-analysis</td><td colspan="4">Dataset A</td></tr>
<tr><td>Treatment</td><td>Dose (kg ai/ha)</td><td>Replicates (n)</td><td>Flowering stem Per 100m^2</td></tr>
<tr><td>2,4-D</td><td>2.1</td><td>3</td><td>8</td></tr>
<tr><td>MCPA</td><td>1.98</td><td>11</td><td>7</td></tr>
<tr><td>Dichlorprop</td><td>2.8</td><td>1</td><td>0</td></tr>
<tr><td>Graslam</td><td>2.9</td><td>3</td><td>2.67</td></tr>
<tr><td>Control</td><td>0</td><td>7</td><td>67.57</td></tr>
<tr><td>Intervention & Comparator</td><td colspan="4">Control of S. jacobaea in partly sprayed fields (Dataset B)
Two fields were partly treated using MCPA herbicide for control of common ragwort. The other half of the field was left as a control (no treatment). Spraying was undertaken in June/July of 1979 with a follow-up of 12 months.</td></tr>
<tr><td rowspan="4">Outcomes used within systematic review meta-analysis</td><td colspan="4">Dataset B</td></tr>
<tr><td>Treatment</td><td>Dose (kg ai/ha)</td><td>Replicates (n)</td><td>Flowering stem per 100m^2</td></tr>
<tr><td>MCPA</td><td>1.85</td><td>2</td><td>18.5</td></tr>
<tr><td>Control</td><td>0</td><td>2</td><td>257.5</td></tr>
<tr><td>Study design</td><td colspan="4">Site comparison A = 40pts
Control trial B = 60pts</td></tr>
<tr><td>Baseline comparison</td><td colspan="4">Size of plots, location, soil type and altitude are all dissimilar or unknown. Habitat and plant age are known and similar. A = 2pts
All baseline compartors are similar. B = 5pts</td></tr>
<tr><td>Intra treatment variation</td><td colspan="4">Plant age and habitat similar. Altitude and location are dissimilar within the arms. A = 2pts
The altitude and location also documented similar. B = 4pts</td></tr>
<tr><td>Measurement of intervention and co-interventions</td><td colspan="4">Intervention measures are even in each arm of the study. Other co-interventions being undertaken on the sites are documented and data is removed from the analysis. 2pts</td></tr>
<tr><td>Replication & parameter of abundance</td><td colspan="4">Replication is uneven between arms with either 1-11 in treatment group and 7 in the control. 2pts</td></tr>
<tr><td>Attrition bias</td><td colspan="4">Dataset A had 20% losses to follow-up. 1pts
Dataset B had no losses to follow-up. 2pts</td></tr>
<tr><td rowspan="2">Data Quality Score Total</td><td colspan="2">Dataset</td><td>A</td><td>B</td></tr>
<tr><td colspan="2">Pts</td><td>49</td><td>76</td></tr>
</table>

<table>
<tr><td>Other data presented in study however not used in review meta-analysis</td><td colspan="5">Field Trials
MCPA (2.3 kg ai/ha) & 2,4-D ester (1.7kg ai/ha) were applied on a number of treatment dates to plots with moderate light ragwort present near sea-level at Loissemouth and at a 2nd site at 210m asl at Boat of Garten. Applied with Land Rover-mounted boom sprayer, fan nozzle, 2.8 bar pressure 225 l/ha of water. Plots measured 9.5 x 40m. No replication was undertaken. Results are in % of ragwort controlled.</td></tr>
<tr><td rowspan="15">Associated Outcomes</td><td></td><td colspan="2">July 1979</td><td colspan="2">July 1980</td></tr>
<tr><td>Spray date</td><td>2,4-D</td><td>MCPA</td><td>2,4-D</td><td>MCPA</td></tr>
<tr><td><u>Lossiemouth</u></td><td></td><td></td><td></td><td></td></tr>
<tr><td>20 April</td><td>63</td><td>26</td><td>56</td><td>38</td></tr>
<tr><td>27 April</td><td>93</td><td>59</td><td>98</td><td>89</td></tr>
<tr><td>4 May</td><td>96</td><td>92</td><td>100</td><td>98</td></tr>
<tr><td>12 May</td><td>71</td><td>72</td><td>100</td><td>97</td></tr>
<tr><td>19 May</td><td>90</td><td>85</td><td>100</td><td>100</td></tr>
<tr><td>4 June</td><td>89</td><td>31</td><td>100</td><td>92</td></tr>
<tr><td>12 June</td><td>90</td><td>73</td><td>100</td><td>90</td></tr>
<tr><td><u>Boat of Garten</u></td><td></td><td></td><td></td><td></td></tr>
<tr><td>11 May</td><td>100</td><td>100</td><td>100</td><td>99</td></tr>
<tr><td>18 May</td><td>100</td><td>54</td><td>100</td><td>48</td></tr>
<tr><td>1 June</td><td>92</td><td>88</td><td>100</td><td>98</td></tr>
<tr><td>9 June</td><td>66</td><td>69</td><td>100</td><td>100</td></tr>
<tr><td>15 June</td><td>61</td><td>46</td><td>100</td><td>100</td></tr>
<tr><td>Other notes</td><td colspan="5">Reduced control was seen in both 2,4-D and MCPA when there was rain within 5 hours of spraying.
Table 4 of the paper gives leaf surface waxiness of ragwort. No support is given to the hypothesis that herbicide susceptibility in ragwort is related to this characteristic.
In the year after spring spraying seedlings are more susceptible to MCPA and 2,4-D than year-old plants.
“The variability in ragwort control in the year of spring spraying probably reflects the fact that rosettes, though less resistant than plants at the stem elongation or flower-bud stage, are of marginal susceptibility to herbicides, and any factor (user, plant or environment) which is not optimum may result in poor control”.</td></tr>
</table>

Study 12	Forbes, J. C. (1982)		
Methods	Two randomised control trial (RCT) designed experiments for effectiveness of herbicides & spray date on the control of ragwort.		
Population	Size of experimental area:	6 x 20m	
	Habitat:	Barley stubble field undersown with perennial ryegrass (*Lolium perenne*) and white clover (*Trifolium repens*) with a heavy infestation of ragwort.	
	Location:	Depends on experiment see below.	
	Altitude:	Unknown.	
	Plant age at time of treatment:	All ages of ragwort.	
	Soil type:	Light sandy soil.	
Intervention & Comparator	**Experiment 1 – Lossiemouth, Moray, Scotland** Herbicide application was undertaken in mild, calm dry weather on 2nd November 1979 using a knapsack sprayer fitted with a wide-angle fan nozzle and delivering about 225 l/ha. Replication in the original experiment was twice. Herbicides used included Asulam; Benazolin + 2,4-DB + MCPA mix ("Ley-Cornox"); 2,4-DB; 2,4-DB + MCPA mix ("Embutox Plus"); MPCB; MCPB + MCPA mix ("Tropotox plus"); 2-4-D ester and MCPA. **Please Note** – Control plots results are not given. A regression calculation for the expected values of treated plots was presented this was used with the mid-point (119.5 ragwort plants) of pre-treatment counts (as data was not presented) to give the expected number of ragwort plants at follow-up time. From this the % control is worked out to give the treatment values and the expected is used as the control.		
Outcomes used within systematic review meta-analysis	**All sprayed on the 2nd November 1979**		
	Treatment	**Dose (kg ai/ha)**	**No. of ragwort plants**
	Asulam	**1.7**	**9.56**
	Benazolin + 2,4-DB + MCPA	**7 litres/ha**	**44.61**
	2,4-DB	**3.4**	**81.26**
	2,4-DB + MCPA	**2.3**	**33.46**
	MCPB	**3.4**	**28.68**
	MCPB + MCPA	**2.3**	**36.64**
	2,4-D	**1.7**	**0**
	MCPA	**2.3**	**1.59**
	Control	**0**	**159.32**
Study design	Randomised control trial (RCT).		**80pts**
Baseline comparison	Except for altitude, all factors are known and suitably similar for comparison.		**5pts**
Intra treatment variation	Again except for altitude, all factors are known and suitably similar for comparison.		**3pts**
Measurement of intervention and co-interventions	Intervention measures are even in each arm of the study. No other co-interventions undertaken during experiment.		**2pts**
Replication & parameter of abundance	2 replicates in the original study per herbicide. 8 plots were left unsprayed.		**2pts**
Attrition bias	No losses to follow-up.		**2pts**
Data Quality Score Total			**94pts**

<table>
<tr><td>Other data presented in study however not used in meta-analysis</td><td colspan="5">Experiment 2
Herbicides applied in autumn 1980 to 6 x 20m plots in a randomised block experiment, with 3 blocks at each of the 3 sites, 1 of which was discarded due to tractor damage. 1 site was an old perennial ryegrass-based pasture at Aberdeen, rich in white clover, heavily infested with ragwort. The other, at Lossiemouth was as used above. Spraying carried out on 2 dates at each site, using same equipment as above. Rain fell shortly after the 2nd application at the Aberdeen site. Follow-up was undertaken on 30th June 1981 at Aberdeen. Results presented for Lossiemouth are not applicable to this systematic review due to presenting total herbage not ragwort control. Conversion of data as above could not be undertaken as formula not presented, therefore the data presented is a timeseries.</td></tr>
<tr><td rowspan="10">Associated Outcomes</td><td colspan="5">Ragwort control and clover mortality at Aberdeen</td></tr>
<tr><td>Date app.</td><td>Herbicide</td><td>Dose (kg ai/ha)</td><td>Ragwort control %</td><td>Clover mortality %</td></tr>
<tr><td>10 Oct</td><td>Asulam</td><td>1.1</td><td>89</td><td>2</td></tr>
<tr><td></td><td></td><td>1.7</td><td>94</td><td>3</td></tr>
<tr><td></td><td></td><td>2.3</td><td>96</td><td>-5</td></tr>
<tr><td></td><td>2,4-D ester</td><td>1.7</td><td>97</td><td>31</td></tr>
<tr><td>21 Nov</td><td>Asulam</td><td>1.1</td><td>10</td><td>3</td></tr>
<tr><td></td><td></td><td>1.7</td><td>-13</td><td>-11</td></tr>
<tr><td></td><td></td><td>2.3</td><td>6</td><td>-28</td></tr>
<tr><td></td><td>2,4-D ester</td><td>1.7</td><td>82</td><td>-2</td></tr>
<tr><td>Other notes</td><td colspan="5">A weakness of Asulam is its dependence on dry weather after spraying, especially in autumn. Furthermore, where the sward is rich in Asulam-sensitive grasses such as Holcus spp. Agrostis spp. And Poa spp. Some reduction in herbage yield can be expected.</td></tr>
</table>

<table>
<tr><th>Study 13</th><th colspan="5">Fryer, J. D. (1953)</th></tr>
<tr><td>Methods</td><td colspan="5">A series of control trials looking at the reasons why spraying sometimes eliminated ragwort while at other times failed to give appreciable control. 20 experiments were sprayed during 1952, 9 all volume rates, 10 high volume and 1 low volume. All but 4 experiments (not presented) were concluded with full observations pre and post spraying.</td></tr>
<tr><td rowspan="6">Population</td><td colspan="2">Size of experimental area:</td><td colspan="3">18.2 x 4.55m & 5.46 x 3.64m.</td></tr>
<tr><td colspan="2">Habitat:</td><td colspan="3">Unknown</td></tr>
<tr><td colspan="2">Location:</td><td colspan="3">Varies with each plot, includes Oxfordshire, North & Wales.</td></tr>
<tr><td colspan="2">Altitude:</td><td colspan="3">Unknown</td></tr>
<tr><td colspan="2">Plant age at time of treatment:</td><td colspan="3">Varies with plot – data is presented</td></tr>
<tr><td colspan="2">Soil type:</td><td colspan="3">Unknown</td></tr>
<tr><td>Intervention & Comparator</td><td colspan="5">Dataset A-C
The combination of 3 doses (0.42 kg ai/ha) of 2,4-D compared to a control of no treatment, to control the ragwort plant from flowering. Results presented as: % reduction, based on pre-spraying counts, of flowering shoots.
8 experiments were presented showing the mean of all volumes (82.54 l/ha) at each dose rate, 1 experiment was at low volume (10.92 l/ha) at each dose rate & 5 experiments were at high volumes (av.163.9 l/ha) at each dose rate. The stage of ragwort growth was recorded for all experiments (I = Early bud stage, II = Bud stage, no sign of flowering, III = Late bud stage, 1st flowers opening, IV = Late bud stage, 1st flowers fully expanded, V = flowering). The longest (12 month) follow-up time was taken.</td></tr>
<tr><td rowspan="4">Outcomes used within systematic review meta-analysis</td><td>Data</td><td>Spray volume</td><td>0.42 kg ai/ha</td><td>Control (no treatment)</td><td>Stage of growth</td></tr>
<tr><td>A</td><td>Av. (82.54 l/ha)</td><td>98.04</td><td>72.00</td><td>II – V</td></tr>
<tr><td>B</td><td>Low (10.92 l/ha)</td><td>96.00</td><td>-30.00</td><td>IV</td></tr>
<tr><td>C</td><td>High (163.9 l/ha)</td><td>99.27</td><td>-39.60</td><td>I - IV</td></tr>
<tr><td>Intervention & Comparator</td><td colspan="5">Dataset (D-F)
The combination of 3 doses (0.42 kg ai/ha) of 2,4-D compared to a control of no treatment, to control the ragwort plant. The results are presented as % reduction, based on pre-spraying counts, of rosettes and seedlings.
7 experiments were presented showing the mean of all volumes (82.54 l/ha) at each dose rate, 1 experiment was at low volume (10.92 l/ha) at each dose rate & 5 experiments were at high volumes (av.163.9 l/ha) at each dose rate.</td></tr>
<tr><td rowspan="4">Outcomes used within systematic review meta-analysis</td><td>Data</td><td>Spray volume</td><td colspan="2">0.42 kg ai/ha</td><td>Control (no treatment)</td></tr>
<tr><td>D</td><td>Av. (82.54 l/ha)</td><td colspan="2">61.24</td><td>26.14</td></tr>
<tr><td>E</td><td>Low (10.92 l/ha)</td><td colspan="2">-431</td><td>-688</td></tr>
<tr><td>F</td><td>High (163.9 l/ha)</td><td colspan="2">73.11</td><td>5.2</td></tr>
</table>

Intervention & Comparator	**Dataset G-I** Three different treatment regimes (0.54kg ai/ha in June 1950, 0.54kg ai/ha in June and 0.36kg ai/ha in October 1950, 0.54kg ai/ha in June 1950 and 0.36kg ai/ha in April 1951) all at 182 l/ha at two different sites (mean taken) were used to investigate effect of 2,4-D on controlling ragwort. The sites were at Austerfield and Dunnington (Yorks/Lancs, U.K.), with plots of 3.6m x 5.4m. The original experiment was replicated. Application of the herbicide was done using a knapsack sprayer. Sites were mown after 2 weeks to prevent seeding directly on to the plots. Results are **% reduction of flowering plants based on pre-counts**. Data is non-independent.

Outcomes used within systematic review meta-analysis	**Data**	**Treatment**	**%**
	G	**0.54kg ai/ha in June 1950**	**7.5**
	H	**0.54kg ai/ha June & 0.36kg ai/ha Oct 1950**	**2.0**
	I	**0.54kg ai/ha June 1950 0.36kg ai/ha April 1951**	**1.5**
		Control for all treament	**200**

Study design	Control Trial. **60pts**
Baseline comparison	Size of plots, location of experiments and age of plants known and comparable. Altitude, habitat and soil type all unknown. **3pts**
Intra treatment variation	Plant age and location are comparable. Altitude and habitat are unknown. **2pts**
Measurement of intervention and co-interventions	Intervention was unequal. No other co-interventions. **1pts** For datasets **G – I** the intervention was equal. **2pts**
Replication & parameter of abundance	Unknown replication in the original study. Parameter of abundance is objective (% flowering stem reduction). **0pts**
Attrition bias	No losses to follow-up in presented experimental data (However there were 4 losses to the original design of the experiment). **2pts**

Data Quality Score Total	**A – C**	**D – F**	**G – I**
	68	**68**	**69**

Other data presented in study however **not used** in review meta-analysis	**Effect of volume rate** Below is a table showing the % reduction, based on pre-spraying counts of flowering shoots 12 months after treatment. The lack of control has meant that it could not be included in the meta-analysis. LV = low volume, MV = medium volume & HV = high volume.

Associated Outcomes		0.18 kg ai/ha			0.36 kg ai/ha			0.72 kg ai/ha		
	Exp	LV	MV	HV	LV	MV	HV	LV	MV	HV
	204	98	98	99	99	-	100	100	99	100
	209	98	100	100	96	100	100	99	100	99
	212	98	98	99	100	100	100	100	99	100
	213	97	90	98	97	98	99	96	96	99
	215	95	100	99	99	100	99	100	99	100
	216	77	88	85	88	95	95	96	99	98
	218	100	100	100	100	100	100	100	100	100

Other data presented in study however **not used** in review meta-analysis	**Effect of volume rate (combination of 0.42kg ai/ha)** As above however the mean of all the doses at each volume against the control of seedlings & rosettes 3 and 12 months after treatment.

Associated Outcomes		Autumn 1952 (3 months)			Summer 1953 (12 months)		
	Exp N^{o}	LV	MV	HV	LV	MV	HV
	204	100	100	100	95	94	98
	209	99	99	100	42	51	45
	212	98	94	99	61	73	56
	213	100	100	100	53	25	6
	215	-	-	-	74	93	87
	216	-	-	-	30	56	63
	218	-2	22	3	57	73	51

Study 14	Fryer, J. D. & Makepeace, R. J. (1956)					
Methods	A control trial to investigate the yield of viable ragwort seeds from plants surviving treatment of 2,4-D (amine) in the year of spraying.					
Population	Size of experimental area:	3 plots – unknown size.				
	Habitat:	Unknown				
	Location:	U.K. Hants, Hereford, Glos, Wilts, Leics.				
	Altitude:	Unknown				
	Plant age at time of treatment:	See below.				
	Soil type:	Unknown				
Intervention & Comparator	**No data to be meta-analysed**					
Outcomes used within systematic review meta-analysis	**No data to be meta-analysed**					
Other data presented in study however **not used** in review meta-analysis	<u>Seed viability from spray surviving previous 2,4-D treatment.</u> The mean of 3 experiments as presented within the original study.					

Approx stage of growth of flowering shoots	Dose (kg ai/ha)	Total (in millions)	Viable (in millions)
Beginning of shooting – flower-buds	0.14	20	12
	0.27	3.9	1.6
	0.54	0	0
Early bud stage	0.14	96	83
	0.27	1.8	0.7
	0.54	1.4	0.3
Late bud stage – early flowering	0.14	830	510
	0.27	360	130
	0.54	100	12
Unsprayed Plants	0	1,320	1,080

Other data presented in study however **not used** in review meta-analysis	<u>Percent mortality of flowering shoots of ragwort in the year of treatment after spraying with 2,4-D (anime)</u> This presents the mean of 3 replicates and 3 doses (0.315 kg ai/ha) at 5 locations.

Associated Outcomes	Stage of growth	Location of Experiment				
		Hants	Hereford	Glos	Wilts	Leics
	Beginning of shooting of flower buds to appear	74	84	92	88	96
	Early bud	87	68	58	66	89
	Late bud	54	-	30	-	81
	Early flowering	-	16	-	49	-

Other notes	

<table>
<tr><th>Study 15</th><th colspan="8">Harper, D. R. (1976)</th></tr>
<tr><td>Methods</td><td colspan="8">A series of well replicated randomised control trials (RCTs) undertaken during the 1973-1974</td></tr>
<tr><td rowspan="6">Population</td><td colspan="5">Size of experimental area:</td><td colspan="3">Dependent on the experiment, see below.</td></tr>
<tr><td colspan="5">Habitat:</td><td colspan="3">Uncropped & cropped areas with Alfalfa (see data below for more details).</td></tr>
<tr><td colspan="5">Location:</td><td colspan="3">U.S.A., western Oregon.</td></tr>
<tr><td colspan="5">Altitude:</td><td colspan="3">Unknown</td></tr>
<tr><td colspan="5">Plant age at time of treatment:</td><td colspan="3">Dependent on the experiment, see below.</td></tr>
<tr><td colspan="5">Soil type:</td><td colspan="3">Silt loam soils</td></tr>
<tr><td>Intervention & Comparator</td><td colspan="8">Field Experiment 1 (Dataset A-D)
A non-cropped area near Albany, Oregon was used to evaluate the efficiency of asulam and 2,4-D on common ragwort plants in various growth stages. Asulam was applied at 1.1, 2.2 & 4.5kg ai/ha at a carrier volume 430 l/ha, 2,4-D was applied at 3.4kg ai/ha at low volume. Application of herbicides was with a bicycle-wheel compressed-air plot sprayer. The weather was good, air temperature 23^{o}C; soil temp. 21^{o}C; 0% cloud cover; 40% rel. humidity; 0-5mph wind speed. After the spray had dried, selected plants were flagged for evaluation due to their size. These ranged from 0-10cm rosettes; 10-20cm rosettes; Initial bolt (flower stalk less than 20cm); Full bolt (flower stalk more than 20cm). The treatments were replicated 3 times with at least 4 plants per size per replicate. The plants were evaluated individually using 0-100% scale (0% no effect – 100% total death). Data was taken from Appendix table 2 of PhD thesis.</td></tr>
<tr><td rowspan="7">Outcomes used within systematic review meta-analysis</td><td></td><td></td><td></td><td colspan="4">Stage of growth</td></tr>
<tr><td>Dataset</td><td>Treatment</td><td>Dose kg/ha</td><td>Rosette</td><td>10-20cm Rosette</td><td>Initial Bolt</td><td>Full Bolt</td></tr>
<tr><td>A</td><td>Asulam</td><td>1.1</td><td>99.2</td><td>94.0</td><td>90.0</td><td>64.0</td></tr>
<tr><td>B</td><td>Asulam</td><td>2.2</td><td>99.6</td><td>99.3</td><td>97.0</td><td>74.0</td></tr>
<tr><td>C</td><td>Asulam</td><td>4.5</td><td>100.0</td><td>99.4</td><td>97.0</td><td>92.0</td></tr>
<tr><td>D</td><td>2,4-D (lv)</td><td>3.4</td><td>100.0</td><td>100.0</td><td>96.0</td><td>71.0</td></tr>
<tr><td></td><td>Control</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Intervention & Comparator</td><td colspan="8">Field Experiment 2 (Dataset E-F)
Experiment undertaken in commercial alfalfa fields near Sheridan, Oregon. Asulam was applied at 0.6; 1.1; 1.7; 2.2; 4.5 kg ai/ha. Treatment was applied on either March 22nd or April 10th 1973. Follow-up was undertaken on August 12th 1973 after the 3rd cut of the field. The experiment was replicated 3 times.</td></tr>
<tr><td rowspan="11">Outcomes used within systematic review meta-analysis</td><td colspan="2">Dataset</td><td colspan="3">Asulam (kg ai/ha)</td><td colspan="3">% Ragwort control</td></tr>
<tr><td colspan="2">E^{1}</td><td colspan="3">0.6</td><td colspan="3">62</td></tr>
<tr><td colspan="2">E^{2}</td><td colspan="3">1.1</td><td colspan="3">68</td></tr>
<tr><td colspan="2">E^{3}</td><td colspan="3">1.7</td><td colspan="3">77</td></tr>
<tr><td colspan="2">E^{4}</td><td colspan="3">2.2</td><td colspan="3">83</td></tr>
<tr><td colspan="2">E^{5}</td><td colspan="3">4.5</td><td colspan="3">99</td></tr>
<tr><td colspan="2">Control</td><td colspan="3">0</td><td colspan="3">0</td></tr>
<tr><td colspan="2">F^{1}</td><td colspan="3">0.6</td><td colspan="3">30</td></tr>
<tr><td colspan="2">F^{2}</td><td colspan="3">1.1</td><td colspan="3">60</td></tr>
<tr><td colspan="2">F^{3}</td><td colspan="3">1.7</td><td colspan="3">88</td></tr>
</table>

	F^4	**2.2**	**93**
	F^5	**4.5**	**100**
	Control	**0**	**0**

Intervention & Comparator	**Field Experiment 3 (Dataset G-K)** Experiment undertaken in commercial alfalfa fields in Oregon. Asulam was applied at 0.6; 1.1; 1.7; 2.2; 4.5 kg ai/ha. Treatment was applied in March; follow-up was undertaken on August 12th 1973 after the 3rd cut of the field. The experiment is a combination of 6 replicates.

Outcomes used within systematic review meta-analysis	**Dataset**	**Asulam (kg ai/ha)**	**% Ragwort control**
	G	**0.6**	**29.17**
	H	**1.1**	**64.17**
	I	**1.7**	**64.17**
	J	**2.2**	**74.17**
	K	**4.5**	**87.50**
	Control	**0**	**0**

Intervention & Comparator	**Field Experiment 4 (Dataset L-Q)** Experiment was conducted in a ragwort infested perennial ryegrass (*Lolium perenne*), orchardgrass (*Dactylis glomerata*) and white clover (*Trifolium repens*) pasture near Scio, Oregon in 1973 to determine the effect of varying carrier volume with (.2) and without (0) surfactant. Asulam was applied at 0.6, 1.1, 1.6, 2.2 & 4.5 kg ai/ha in 94, 187 & 374 l/ha of water. Ragwort plants between 8-13cm rosettes used. The weather was good, air temperature 24°C; soil temp. 21°C; foliage conditions dry; 60% rel. humidity.

Outcomes used within systematic review meta-analysis		**Datasets (L-Q)**					
	Carrier Volume	**94**	**187**	**374**	**94**	**187**	**374**
	Surfactant %	**0**	**0**	**0**	**0.2**	**0.2**	**0.2**
	Doses (kg ai/ha)	**L**	**M**	**N**	**O**	**P**	**Q**
	0	**0**	**0**	**0**	**0**	**0**	**0**
	0.6	**53.8**	**45.0**	**57.5**	**66.3**	**73.8**	**63.8**
	1.1	**78.8**	**82.5**	**90.0**	**81.3**	**87.5**	**92.3**
	1.6	**93.3**	**92.0**	**98.0**	**95.8**	**92.5**	**98.3**
	2.4	**98.0**	**97.5**	**100.0**	**98.8**	**99.0**	**100.0**
	4.5	**99.0**	**99.5**	**99.5**	**99.0**	**99.0**	**100.0**

Intervention & Comparator	**Field Experiment 5-6 (Dataset R^{1-4})** Experiments conducted near Rickreall, Oregon to study various rates of Asulam for ragwort control in established alfalfa. Dose rates were 4.5 (4 replicates); 8.9; 8.9 with 0.2% surfactant (both at 7 replicates); 2.16 kg ai/ha (a combination of 2.1; 2.2 & 2.5 – totalling 10 replicates). All treatments applied on 16th April 1974. Method of application was broadcast spray with carrier volume of 271 l/ha, nozzle size 8002 and a 35 pressure.

Outcomes used within systematic review meta-analysis	**Dataset**	**Treatment**	**Dose (kg ai/ha)**	**Mean**
	R^1	**Asulam**	**2.16**	**76.00**
	R^2	**Asulam**	**4.5**	**83.75**
	R^3	**Asulam**	**8.9**	**88.57**
	R^4	**Asulam**	**8.9 + 0.2% surf**	**90.00**
		Control	**0**	**0**

Study design	Randomised Control Trial	**80pts**
Baseline comparison	All baseline comparators except the altitude are known.	**5pts**
Intra treatment variation	Again all comparators are equal and known apart from altitude.	**3pts**
Measurement of intervention and co-interventions	No co-intervention undertaken and even interventions.	**2pts**

<table>
<tr><td>Replication & parameter of abundance</td><td colspan="6">12 replicates in each arm of the study – however parameter of abundance a subjective, visual assessment.
4pts.</td></tr>
<tr><td>Attrition bias</td><td colspan="6">No losses to follow-up. 2pts</td></tr>
<tr><td rowspan="2">Data Quality Score Total</td><td>Dataset</td><td>A-D</td><td>E-F</td><td>G-K</td><td>L-Q</td><td>R</td></tr>
<tr><td>Pts</td><td>96</td><td>96</td><td>96</td><td>96</td><td>96</td></tr>
<tr><td>Other notes</td><td colspan="6">From the authors results, summary and conclusions section:
Growth of rosettes were reduced and new leaves formed at the centre were chlorotic and stunted. At all rates, this led to the death of small rosettes. Doses of 1.1kg ai/ha or higher resulted in 90% control or more in all growth stages but fully bolted. At all rates, bolted plants showed some recovery, evidenced by lateral bud break. Author suggests that Asulam at rates of 1.1 – 2.2 kg ai/ha can give excellent control of rosette plants. However 4.5 kg ai/ha is needed for good control of bolted plants.
Ragwort control was concluded not to be influenced by an increase of carrier volume from 94 to 374 l/ha. Significant difference was recorded between no surfactant and the addition of the surfactant, however only at low values which don’t give good control.
Other experiments presented within the thesis showed that Asulam can be used safely and effectively for ragwort within alafalfa fields. Within the field studies Asulam rates of 2.2kg ai/ha consistently gave 70%+ control. Visible alfalfa injury did not occur until 18 kg ai/ha was applied, no yield reduction was found up to 9 kg ai/ha.
In greenhouse experiments alfalfa tolerated over 300 times as much Asulam as ragwort, This ratio lower when surfactant was added, but one hundred-fold differences still recorded.
Ragwort retained over twice as much spray solution as alfalfa when no surfactant was added to the spray, similar values also presented when the surfactant was added. The adding of surfactant did mean that the alfalfa uptake exceeded that of ragwort, without surfactant opposite result achieved.</td></tr>
</table>

Study 16	James, T. K. & Mortimer, J. (1983)				
Methods	Two randomised control trials (RCTs) testing the effectiveness of hexazinone in controlling weed species in a lucerne crop.				
Population	Size of experimental area:	Varied from 7-10 x 1.5-2m, however standard in each experiment.			
	Habitat:	Lucerne crop.			
	Location:	New Zealand, Reporoa.			
	Altitude:	Unknown.			
	Plant age at time of treatment:	Similar range of ages in each plot.			
	Soil type:	Taupo sandy loam soil.			
Intervention & Comparator	**Trial 1 & 2 (Dataset A-D)** Different doses (0.5; 1.0; 1.5; 2.0 kg ai/ha) of hexazinone (Velpar 90% WSP) at different application times. Herbicide applied using a CO_2 powered precision sprayer delivering 290-350 l/ha of solution at 210 kPa. All trials had four replicates, however only the mean is presented. Assessments made by counting the number of plants per plot/m^2.				
Outcomes used within systematic review meta-analysis		**Treatment Date**			
		26/7/79	**27/11/79**	**23/9/80**	**6/11/80**
	Dose (kg ai/ha)	**A**	**B**	**C**	**D**
	0.5	**-**	**-**	**1.25**	**1.55**
	1.0	**-**	**-**	**1.90**	**1.10**
	1.5	**1.27**	**0**	**0.70**	**0.55**
	2.0	**1.53**	**0**	**0.65**	**0.35**
	Control (0)	**1.73**	**1.47**	**2.15**	**2.60**
Study design	Randomised control trial. **80pts**				
Baseline comparison	All baseline comparators similar with the exception of unknown altitude values. **5pts**				
Intra treatment variation	All similar again with the exception of unknown altitude values. **3pts**				
Measurement of intervention and co-interventions	Even experimental design, no other co-interventions. **2pts**				
Replication & parameter of abundance	Well replicated (4 per plot) trials – with an objective parameter of abundance (plants/m^2). **4pts**				
Attrition bias	No losses to follow-up. **2pts**				
Data Quality Score Total	**Dataset**	**A**	**B**	**C**	**D**
	Pts	**96**	**96**	**96**	**96**
Other notes					

Study 17	James, T. K., Rahman, A. & DeJong, P. (1997)					
Methods	A series of control trials testing the effectiveness of a new herbicide flazasulfuron in controlling ragwort at different growth stages.					
Population	Size of experimental area:	2 x 10m.				
	Habitat:	Pasture.				
	Location:	New Zealand, Waikato.				
	Altitude:	Unknown.				
	Plant age at time of treatment:	See below.				
	Soil type:	Unknown.				
Intervention & Comparator	**Trials 1-4 (Datasets A-D)** Trials were conducted over 4 sites on ragwort at varying growth stages. Broadcast applications of 5 doses of flazasulfuron and 1 dose of 2,4-D were compared to no treatment. All herbicide applications were completed with a CO_2 powered precision sprayer fitted with a TeeJet 8003 nozzle at 210 kPa to apply 300 l/ha. Treatments were replicated four times, however only means presented. The growth stages of the ragwort were as follows: Trial 1 were mostly rosettes with some at small cabbage stage; Trial 2 were at the cabbage stage, many multi-crowned; Trial 3 were bolted to bud stage; Trail 4 seedlings and small rosettes. Assessment was a control score 0-100, (0=no damage, 100=compete brownoff).					
Outcomes used within systematic review meta-analysis			**A**	**B**	**C**	**D**
	Treatment	**Dose g ai/ha**	**13 Oct 1994**	**19 Oct 1994**	**28 Oct 1994**	**26 Jun 1995**
	flazasulfuron	**1**	**10**	**14**	**18**	**30**
	flazasulfuron	**2**	**41**	**40**	**50**	**50**
	flazasulfuron	**3**	**63**	**54**	**58**	**63**
	flazasulfuron	**4**	**85**	**55**	**65**	**76**
	flazasulfuron	**5**	**93**	**65**	**75**	**88**
	2,4-D	**1035**	**81**	**21**	**28**	**71**
	Control	**0**	**0**	**0**	**0**	**0**
Intervention & Comparator	**Trials 7-8 (Dataset E-F)** Please know that these trials are labelled as 13-15 in table 3 of the publication. Spot applications of the herbicide flazasulfuron were undertaken on varying plot sizes (all with 20+ ragwort plants/plot). A combination of doses was taken. Growth stages were as follows: Trial 7 mostly rosettes with some small plants present; Trial 8 advanced cabbage stage. Two types of spot applicators that were in common usage were used to compare results. One was a modified drench gun fitted with a solid cone nozzle which applied 5ml doses of herbicide to each plant, the other was a standard knapsack sprayer fitted with a measuring device to apply a 10ml dose of spray mix through a flat fan nozzle. **PLEASE NOT = doses are in g ai/ha**					
Outcomes used within systematic review meta-analysis	**Treatment**	**Dose g ai/litre**	**E 8th Sept 1995**	**F 3rd Oct 1995**		
	Control	**0**	**0**	**0**		
	Flazasulfuron	**0.029@10ml**	**87.00**	**78.00**		
	flazasulfuron	**0.029@5ml**	**98.33**	**93.00**		
Study design	Control trial. **60pts**					
Baseline comparison	Altitude of the fields and the soil type are unknown. All other baseline comparators known and suitably similar. **3pts**					
Intra treatment variation	Again altitude is unknown, others known and suitable. **3pts**					

Measurement of intervention and co-interventions	Experiment evenly designed, no other co-interventions undertaken during the study period. **2pts**		
Replication & parameter of abundance	4 replicates per plot were undertaken in the original study design. However a subjective parameter of abundance was used. **0pts**		
Attrition bias	No losses to follow-up. **2pts**		
Data Quality Score Total	**Dataset**	**A-D**	**E-F**
	Pts	**71**	**71**
Other notes	Flazasulfuron (SL-160, ISK, 25% WDG) is a new (1997) sulfonylurea herbicide similar to thifensulfuron and metsulfuron. Used as a spot treatment (0.05 g/l, 5-10ml/dose) flazasulfuron gave excellent control of ragwort plants and avoided the problem of pasture damage.		

<table>
<tr><th>Study 18</th><th colspan="8">Lawson, S. (1982)</th></tr>
<tr><td>Methods</td><td colspan="8">A series of control trials to investigate the viability of ragwort seeds from plants treated with various herbicides during flowering.</td></tr>
<tr><td rowspan="6">Population</td><td colspan="3">Size of experimental area:</td><td colspan="5">Pots 12.7cm diameter.</td></tr>
<tr><td colspan="3">Habitat:</td><td colspan="5">Originally pasture then pots in a mist propagator (1 week), then cold frame.</td></tr>
<tr><td colspan="3">Location:</td><td colspan="5">Plants originally collected from pasture near Kingswells, Aberdeenshire.</td></tr>
<tr><td colspan="3">Altitude:</td><td colspan="5">Unknown.</td></tr>
<tr><td colspan="3">Plant age at time of treatment:</td><td colspan="5">All similar ages – dense rosettes.</td></tr>
<tr><td colspan="3">Soil type:</td><td colspan="5">3:2 soil and sand mixture.</td></tr>
<tr><td>Intervention & Comparator</td><td colspan="8">No data to be meta-analysed</td></tr>
<tr><td>Outcomes used within systematic review meta-analysis</td><td colspan="8">No data to be meta-analysed</td></tr>
<tr><td>Other data presented in study however not used in review meta-analysis</td><td colspan="8"><u>Seed viability</u>
The timing of spraying (3 different dates – 3rd July, 17th July & 17th August) was coincided with inflorescence formation, full flowering and seed setting. Plants were selected uniformly on each date. Commercial formulations of either 2,4-D ester or glyphosate were used. 3 different doses were applied 0.5; 1.0 or 1.5 kg ai/ha. Each treatment was replicated 3 times and 6 additional plants were unsprayed and used as controls. Herbicides applied using knapsack sprayer and plants placed under cover for a few days after application then replaced in the open cold frame. Seeds collected by hand in August.
<u>2. Straight Germination Test</u>
Samples of 100 seeds from each plant was placed on to a moist germination paper in a Petri dish and kept in a germinator, in light for 10 days, after which assessments were made.</td></tr>
<tr><td rowspan="6">Associated Outcomes</td><td colspan="8">% viability of 3 plants seeds on each date unless superscript with the number of samples. <u>2. Straight Germination Test</u></td></tr>
<tr><td></td><td colspan="3">2,4-D</td><td colspan="3">Glyphosate</td></tr>
<tr><td>Date\Dose</td><td>0.5</td><td>1.0</td><td>1.5</td><td>0.5</td><td>1.0</td><td>1.5</td></tr>
<tr><td>3rd July</td><td>12</td><td>6</td><td>10</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>17th July</td><td>37</td><td>67</td><td>10</td><td>3[2]</td><td>-</td><td>-</td></tr>
<tr><td>17th Aug.</td><td>51</td><td>3[1]</td><td>24</td><td>56</td><td>57</td><td>36</td></tr>
<tr><td>Control</td><td colspan="6">58[6]</td></tr>
<tr><td>Other data presented in study however not used in review meta-analysis</td><td colspan="8"><u>4. Stratification</u>
Samples of 100 seeds from the same plants were placed between 2 moist germination papers in a Petri dish. The dishes were then placed in a refrigerator at a temperature of 6^{0}C for 14 days. The top germination paper was then removed and the samples were placed in a germinator, in light, for 14 days before testing for germination.</td></tr>
<tr><td rowspan="6">Associated Outcomes</td><td></td><td colspan="3">2,4-D</td><td colspan="3">Glyphosate</td></tr>
<tr><td>Date\Dose</td><td>0.5</td><td>1.0</td><td>1.5</td><td>0.5</td><td>1.0</td><td>1.5</td></tr>
<tr><td>3rd July</td><td>20</td><td>12</td><td>6</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>17th July</td><td>40</td><td>52</td><td>40</td><td>0[2]</td><td>-</td><td>-</td></tr>
<tr><td>17th Aug.</td><td>31</td><td>4[1]</td><td>41</td><td>32</td><td>48</td><td>30</td></tr>
<tr><td>Control</td><td colspan="6">63[6]</td></tr>
</table>

Study 19	Makepeace, W. & Thompson, A. (1982)				
Methods	Three randomised control trials (RCT) were conducted in1981-82 to evaluate the usage of rope wick applications of 2 herbicides at different dose rates.				
Population	Size of experimental area:	2 x 30 m plots.			
	Habitat:	Cattle grazed pasture.			
	Location:	New Zealand, Motumaoho, Karakariki Valley & Rangitoto in Waikato & King County districts, North Island.			
	Altitude:	Unknown.			
	Plant age at time of treatment:	See below.			
	Soil type:	Unknown.			
Intervention & Comparator	Ragwort populations were of 1.2 – 2.6 plants m^2. Three dilutions of glyphosate were compared with three dilutions of 2,4-D/picloram of similar viscosity to no treatment. Herbicides were applied 1-2 days after grazing in a double pass in opposite directions using a 2m wide, non-commercial wick applicator fitted with Feltex 14mm polypropylene rope fixed by Rubbercraft $N^{o.}$ 8 grommets and operated 10cm above the pasture at a speed of 3km/h. A separate applicator was used for each herbicide and dilution to ensure freedom from cross-dilution or contamination. 2,4-D/picloram spot treatment was applied with an Oxford Precision sprayer equipped with a $N^{o.}$ 0 fan nozzle. Trial was laid out in a randomised block design with 4 replicates. Assessments were made 3 months after treatment, counts in Inflorescences/m^2.				
Outcomes used within systematic review meta-analysis			**A**	**B**	**C**
	Treatment	**Dose g/litre**	**Cabbage**	**Bolting**	**Flowering**
	glyphosate	**120**	**462**	**187**	**17**
	glyphosate	**72**	**538**	**121**	**13**
	glyphosate	**40**	**776**	**530**	**69**
	2,4-D/picloram	**100/25**	**316**	**58**	**28**
	2,4-D/picloram	**67/17**	**420**	**90**	**51**
	2,4-D/picloram	**40/10**	**407**	**186**	**210**
	2,4-D/picloram	**0.2/0.05**	**19**	**7**	**14**
	Control	**0**	**3846**	**3846**	**3846**
Study design	Randomised control trial. **80pts**				
Baseline comparison	Soil type and altitude are unknown; all other comparators are listed and similar. **4pts**				
Intra treatment variation	Altitude is unknown; all other comparators are listed. **3pts**				
Measurement of intervention and co-interventions	Experiment is even – however only presents the mean of all controls therefore lack independence. Co-interventions are listed and are similar. **2pts**				
Replication & parameter of abundance	Well replicated (4) experiment. Parameter of abundance is objective and accurate. **4pts**				
Attrition bias	No losses to follow-up. **2pts**				
Data Quality Score Total	**Dataset**	**A-C**			
	Pts	**95**			
Other data presented however **not used** in review meta-analysis	<u>The effect of herbicide applied to ragwort at flowering on % viable seed production</u> Overleaf are the results for the above titled experiment for 3 sites				

	used in the first experiment The Rangitoto result could be swayed due to there being rainfall within the 1st 24hours after treatment.				
Associated Outcomes	Treatment	Dose g/l	Motumaoho (mid-flower)	Karakariki (mid-late fl)	Rangitoto (v. early fl.)
	Control	0	59.5	49.5	57
	glyphosate	120	0.0	0.6	26
	glyphosate	72	0.0	0.8	44
	glyphosate	40	0.3	5.4	49
	2,4-D /picloram	100/25	0.0	2.4	44
	2,4-D /picloram	67/17	0.0	2.4	23
	2,4-D /picloram	40/10	1.5	10.0	32
	2,4-D /picloram	0.2/0.05	0.0	3.0	15
Other data presented however **not used** in review meta-analysis	The relative flow rates & transfer rates of glyphosate in rope wicks, results follow.				
Associated Outcomes	Dilution	Rope	Flow rate	ai Transfer	
	1:2	Winstone rope	1.0	1.0	
	1:4	Winstone rope	1.3	0.8	
	1:8	Winstone rope	1.6	0.5	
	1:2	Feltex rope	2.5	2.5	
Other notes	Over the 3 trials rope wick application took approx. 1/10 the time required to spot spray an equivalent area.				

Study 20	Marrs, R. H. (1985)	
Methods	Trials for the effects of potential bracken & scrub control herbicides on lowland *Calluna* and grass heath communities (including effects on *S. jacobaea*).	
Population	Size of experimental area:	2 x 2m plots x 4 blocks x 10.
	Habitat:	Heaths – *Calluna* & grass.
	Location:	U.K., Westleton Heath NNR (TM 455694), Caveham Heath NNR (TM 755694)
	Altitude:	Unknown.
	Plant age at time of treatment:	Unknown.
	Soil type:	Unknown.
Intervention & Comparator	**No data to be meta-analysed**	
Outcomes used within systematic review meta-analysis	**No data to be meta-analysed**	
Other data presented in study however **not used** in review meta-analysis	Nine herbicides (ammonium sulphamate; asulam; glyphosate; hexazinone; fosamine ammonium; picloram; 2,4,5-T; tebuthiuron; triclopyr), were sprayed either on 12th or 30th August 1980. All but tebuthiuron were applied in water at 300 litres/ha, expect ammonium sulphamate = 600 lires/ha, using a knapsack sprayer. No wetting agent used. Tebuthiuron pellets were applied by mixing the pellets in a 100g sample of soil from the sites and sprinkling this mixture as evenly as possible across the plots.	
Associated Outcomes	Treatment	+ increase, 0 no effect, - decrease
	Control (untreated)	0
	Ammonium sulphamate	+
	Asulam	0
	Glyphosate	+
	Hexazinone	+
	Fosamine ammonium	-
	Picloram	0
	2,4,5-T	0
	Tebuthiuron	-
	Triclopyr	+
Other notes		

Study 21	Martin, P., Thompson, A., Saunders, A. E. & Rahman, A. (1986)						
Methods	Trials at 2 sites in the Waikato region during 1985/86 investigating the effect of doses of 2,4-D ester on ragwort plants of various sizes & stages of growth.						
Population	Size of experimental area:	Marked plants – 25 site 1, 42 site 2.					
	Habitat:	Unknown.					
	Location:	New Zealand, Patetonga (site 1), Karakarika (site 2).					
	Altitude:	Unknown.					
	Plant age at time of treatment:	See below.					
	Soil type:	Site 1 = Clevedon silt loam Site 2 = Hamilton clay loam					
Intervention & Comparator	At site 1 plants were either large or small single rosettes or multi-rosette/regrowth plants, site 2 plants were categorized as true seedlings (complete with cotyledons), single rosettes (small or large) or multi-rosette/regrowths (small or large). Plant height, diameter, leaf number, crown diameter and number of rosettes were measured. Site 1 used 4 replicates and Site 2 had 3 replicates. 2,4-D was applied at doses of 1.0; 2.0; 3.5kg ai/ha in 300 litres/ha water. Applications were made using a hand held CO_2 operated 3m boom. Assessments of marked plants were made approx. 6 months after treatment. The **% kill of ragwort** was used as a measurement this was done comparing treated plots to the values for the control plots.						
Outcomes used within systematic review meta-analysis **Site 1**		**Small rosette (<25cm)**	**Large rosette (>25cm)**	**Multi-rosette regrowth**			
	Dose kg ai/ha	**A**	**B**	**C**			
	Control (0)	**27**	**0**	**5**			
	1.0	**90**	**25**	**35**			
	2.0	**90**	**71**	**75**			
	3.5	**100**	**91**	**84**			
Outcomes used within systematic review meta-analysis **Site 2**			**Rosette**			**Regrowth**	
			Seedling	**Small**	**Large**	**Small**	**Large**
		Dose kg ai/ha	**5cm**	**13cm**	**25cm**	**22cm**	**38cm**
			D	**E**	**F**	**G**	**H**
		1.0	**93.67**	**66.67**	**32.00**	**37.00**	**21.00**
		2.0	**97.00**	**81.33**	**69.00**	**48.67**	**46.67**
		3.5	**98.00**	**93.67**	**77.00**	**76.33**	**66.67**
	Control	**0**	**25**	**30**	**7**	**6**	**6**
Study design	Randomised control trial. **80pts**						
Baseline comparison	Altitude and habitat comparators unknown. All other comparators known and suitably similar. **4pts**						
Intra treatment variation	Again altitude and habitat comparators are unknown. Other comparators known and suitably similar. **2pts**						
Measurement of intervention and co-interventions	Experiment is even and no other co-interventions are untaken during the study period. **2pts**						
Replication & parameter of abundance	Well replicated (3 + 4) experiments. Parameter of abundance is objective based on control plots plant counts. **4pts**						
Attrition bias	No losses to follow-up. **2pts**						
Data Quality Score Total	**Dataset**	**A-C**	**D-H**				
	Pts	**94**	**94**				
Other notes	Study presents figures of the effect of dose over time, dose and the stage of development of the plant.						

Study 22	M^{c}Clements, I. (1992)			
Methods	A PhD studying marsh *S. aquaticus* and common *S. jacobaea* ragwort control. Experiments are conducted as randomised control trials.			
Population	Size of experimental area:	See below.		
	Habitat:	See below.		
	Location:	Ireland		
	Altitude:	Unknown		
	Plant age at time of treatment:	See below.		
	Soil type:	See below.		
General Methods for **controlled environment trials**.	Seeds were collected between August & October of 1988 & 1989 from a range of sites in Co. Antrim & Co. Fermanagh. After collection the seeds were cleaned & stored at 5^{o}C until used. Seeds were sown at a depth 1-5mm in seed trays (340x220x50mm) containing a peat based potting medium & placed in an unheated greenhouse where watering was controlled until germination had occurred. Individual plants were transferred into 9cm pots. The medium was a mix of 2 volumes of Shamrock sphagnum peat (Bord-na-mona), 1 volume of grit & 1 of sand. Herbicides were applied using a pot sprayer delivering 314 l/ha through a 8015 Teejet at an operating pressure of 200KPa. Two herbicides were used – MCPA salt (Agroxone 50 s.l; ICI Plant Protection), 2,4-D ester (Iso Planotox 58.9% e.c.; Rhone Poulenc).			
Intervention & Comparator	**Experiment 4.1 (Dataset A-B)** Two thousand seeds of 2 populations of *S. jacobaea*, from Benone, Belcoo, and 2 populations of *S. aquaticus*, from Tamlaght, Drumcrow. Planted as general methods for controlled environment trials above. 24 plants of each population were transplanted into a single tray. The trays were divided into 2 blocks and each block of 40 trays were placed in a Weiss growth cabinet. 6 weeks after sowing each population was sprayed with either 2,4-D ester (0.66kg ai/ha) or MCPA (1.22kg ai/ha). Assessments in mean fresh weight (Fwt/plant) of each population.			
Outcomes used within systematic review meta-analysis	**Dataset**	**2,4-D 0.66kg ai/ha A**	**MCPA 1.22kg ai/ha B**	**Control untreated**
	S. jacobaea	**2.36**	**2.94**	**4.53**
	S. aquaticus	**1.10**	**1.40**	**3.57**
Study design	Randomised control trial. **80pts**			
Baseline comparison	All comparators are known and similar, except for altitude which is unknown. **5pts**			
Intra treatment variation	All comparators known and similar, except for altitude which is unknown. **3pts**			
Measurement of intervention and co-interventions	Experiment is even and no other co-interventions are untaken during the study period. **2pts**			
Replication & parameter of abundance	A well replicated trial. Parameter of abundance is objective. **4pts**			
Attrition bias	No losses to follow-up. **2pts**			
Data Quality Score Total	**Dataset**		**A-B**	
	Pts		**96**	
Other notes				

Study 23	Murphy, J. (2000)			
Methods	A time series experiment by Aventis the marketers of 3 herbicides to compare the effectiveness of their products.			
Population	Size of experimental area:	October trial = 5 sites May trial = 4 sites All of unknown size.		
	Habitat:	Amenity grasslands.		
	Location:	U.K., Unknown.		
	Altitude:	Unknown.		
	Plant age at time of treatment:	Unknown		
	Soil type:	Unknown.		
Intervention & Comparator	**No data to be meta-analysed**			
Outcomes used within systematic review meta-analysis	**No data to be meta-analysed**			
Other data presented in study however **not used** in review meta-analysis	Dicotox Extra (containing 2,4-D ester); Dormone (containing 2,4-D amine); Supertox 30 (containing 2,4-D amine & mecoprop-p) were tested for their effectiveness in ragwort control. The 1st trial was conducted in October 1999 (Autumn) across 5 sites using two doses of each herbicide. The 2nd trial was conducted in May 2000 (Spring) across 4 sites again using the same 2 doses per herbicide. Follow-up was 6 months after treatment (MAT) and recorded as % control of ragwort.			
Associated Outcomes			% control	
	Product	Dose (L/ha)	October trial	May trial
	Dicotox Extra	2.8	93	89
	Dicotox Extra	5.6	95	80
	Dormone	2.8	91	81
	Dormone	5.6	95	78
	Supertox 30	11	94	80
	Supertox 30	17	97	83
Other notes	The advantage of using straight 2,4-D product is that a relatively narrow weed spectrum is targeted. The mixture with mecoprop-p (Supertox 30) will kill a broader spectrum of weed. The ester formulation (Dicotox Extra) is taken up quickly by treated foliage and is therefore very rainfast. The amine formulation (Dormone) is 1 of a very few herbicides approved for use in or near water.			

Study 24	Naish, R. W. (1975)			
Methods	A control trial to compare the effectiveness of a new growth regulating herbicide Dowco 290 to other popular herbicides for their control of ragwort.			
Population	Size of experimental area:	5 x 2m plots.		
	Habitat:	Unknown.		
	Location:	New Zealand,		
	Altitude:	Unknown		
	Plant age at time of treatment:	Multi-crown ragwort plants.		
	Soil type:	Unknown.		
Intervention & Comparator	Broadcast applications of monoethanolamine salt of Dawco 290; 2,4-D amine; picloram (K salt) & mixtures of each were applied at doses as presented in the table below. Ragwort was in the multi-crown stage of growth up to 20cm high. Follow-up period of was 28 weeks after treatment with the results presented as% regrowth. These were converted into % control allowing for uniformity of data for meta-analysis.			
Outcomes used within systematic review meta-analysis	**Treatment**	**Dose (kg ai/ha)**	**% regrowth**	**% control**
	Picloram/2,4-D	**0.125/0.25**	**25**	**75**
		0.25/1.0	**10**	**90**
	Dowco 290/2,4-D	**0.125/0.25**	**40**	**60**
		0.25/1.0	**30**	**70**
	2,4-D amine	**2.0**	**55**	**45**
	Dowco 290	**0.25**	**15**	**85**
	Picloram	**0.25**	**20**	**80**
	Control	**0**	**100**	**0**
Study design	Control Trial			**60pts**
Baseline comparison	Size of experimental areas, location and plant age all known and similar. Habitat, soil type and altitude are unknown.			**3pts**
Intra treatment variation	Plant age and location are known, however habitat and altitude are both unknown.			**2pts**
Measurement of intervention and co-interventions	Experiment is even, there are no other co-interventions.			**2pts**
Replication & parameter of abundance	No replication was undertaken in the original experiment.			**0pts**
Attrition bias	No losses to follow-up.			**2pts**
Data Quality Score Total				**69pts**
Other notes				

Study 25	Radcliffe, J. E. (1969)		
Methods	Spring applications of 3 herbicides were tested for their effectiveness in controlling ragwort. Timeseries data presented.		
Population	Size of experimental area:	Unknown	
	Habitat:	Unknown	
	Location:	New Zealand	
	Altitude:	Unknown	
	Plant age at time of treatment:	Unknown	
	Soil type:	Unknown	
Intervention & Comparator	**No data to be meta-analysed**		
Outcomes used within systematic review meta-analysis	**No data to be meta-analysed**		
Other data presented in study however **not used** in review meta-analysis	Timeseries data of the 2,4-D; Picloram & 2,4-D mixture (Tordon) at 0.2/0.9kg ai & Dicamba & 2,4-D at 0.3/1.4 kg ai. Based on spring application in combination with good management (not listed).		
Associated Outcomes	Treatment	Dose kg ai/ha	% Ragwort Kill
	Picloram & 2,4-D	23-45 g ai/ha	95
	Dacamba & 2,4-D	45-90g ai/ha	90-95
	2,4-D	181-363g ai/ha	75
Other notes			

Study 26	Richards, M. C., Swift, G., Cleland, A. T. & Davies, D. H. K. (1983)							
Methods	A series of timeseries trials of 3,6-dichloropicolinic acid, triclopyr, 2,4-D ester and MCPA, alone and in mixtures for control of *S. jacobaea* on grasslands.							
Population	Size of experimental area:				3 x 10m plots			
	Habitat:				Grazing fields, on lowland farms.			
	Location:				U.K., East Scotland			
	Altitude:				Lowlands			
	Plant age at time of treatment:				Rosette or flowering plant			
	Soil type:				Unknown			
Intervention & Comparator	**No data to be meta-analysed**							
Outcomes used within systematic review meta-analysis	**No data to be meta-analysed**							
Other data presented in study however **not used** in review meta-analysis	Five trials between 1979-81 were performed on lowland farm, grazing fields in East Scotland. Infestations of *S. jacobaea* varied from 0.3plants m^{-2} on a rotational grass site to 15 plants m^{-2} on a rotational pasture. Herbicides were applied by a Van der Weij small plot sprayer with Teejet 8003 nozzles. Pressure was 2 bar and volume 200/400 l/ha dependant on sward density. Timing of treatment was Oct/Nov or May/June. Trials were fenced for 3-5 weeks to keep out stock. Each treatment was replicated 3 times, with the **% control** of untreated plots assessed in July/August 1 year & 2 years after treatment is presented.							
Associated Outcomes			Oct/Nov treatment			May/June treatment		
				Mean % control			Mean % control	
	Treatment	Dose kg ai/ha	No. of sites	Rosettes	Flowering Plants	No. of sites	Rosettes	Flowering Plants
	2,4-D	1.7	3	0	86	5	94	98
	MCPA	2.3	3	18	81	3	88	68
	3,6-DCPA	0.2	3	51	85	3	92	78
	Triclopyr	1.44	3	0	52	3	92	93
	3,6-DCPA /Triclopyr	0.1/0.96	3	26	88	3	83	93
	3,6-DCPA /Triclopyr	0.1/0.48	0	-	-	2	91	100
	2,4-D /Triclopyr	0.85/0.48	0	-	-	2	83	100
	2,4-D /Triclopyr	1.7/0.48	0	-	-	2	89	100
	2,4-D/ 3,6-DCPA	0.85/0.1	0	-	-	2	91	100
	2,4-D/ 3,6-DCPA	1.7/0.1	0	-	-	2	89	100
Other notes	Clover was reduced by 2,4-D and MCPA. It was eliminated by the other treatments.							

Study 27	Schmidl, L. (1964)			
Methods	Trials of aerial spraying of *S. jacobaea* in Australia with 2,4-D. Data is presented without control however an initial value is given.			
Population	Size of experimental area:	Unknown		
	Habitat:	Unkept grasslands.		
	Location:	Australia, South Gippsland and Otway Ranges.		
	Altitude:	Unknown		
	Plant age at time of treatment:	All ages.		
	Soil type:	Unknown		
Intervention & Comparator	**No data to be meta-analysed**			
Outcomes used within systematic review meta-analysis	**No data to be meta-analysed**			
Other data presented in study however **not used** in review meta-analysis	<u>Ariel spraying in different localities</u> 2,4-D was applied at 0.9 kg ai @ 18 l/ha, at 4 sites, using a fixed wing aircraft. In 2 of the locations a 2nd treatment was applied in the following year.			
Associated Outcomes		Av. N°. of ragwort plants per $0.3m^{-2}$		
	Site	Initial	After 1st treat	After 2nd treat
	Leongatha (1)	6	3	-
	Leongatha (2)	7	3	1
	Welshpool	6	2	1
	Forrest	6	1	-
Other data presented in study however **not used** in review meta-analysis	<u>Volume of spray liquid required</u> A variety of volumes of spray were assessed to see which delivered the standard 0.9 kg ai best to give effective ragwort control.			
Associated Outcomes	Volume of spray Litres per hectare	Av. N°. of ragwort plants per $0.3m^{-2}$		
		Initial	After treatment	
	18.2	7	2	
	10.9	5	1	
	3.6	6	0	
Other notes	A helicopter delivery produced a higher % of reduction than a fixed wing aircraft.			

Study 28	Shiban, A. (1976)							
Methods	A series of experiments on various aspects of ragwort control using a mixture of herbicides.							
Population	Size of experimental area:						Pots.	
	Habitat:						Unknown lab conditions.	
	Location:						U.K., Scotland.	
	Altitude:						Unknown.	
	Plant age at time of treatment:						3 months old.	
	Soil type:						Unknown.	
Intervention & Comparator	**Experiment 3 – Effect of herbicide on 3-month-old ragwort seedlings** Seedlings at the 3-leaf stage were sprayed with a range of herbicides and concentrations. 10 seedlings were transplanted into a pot and each pot received 3.3ml of herbicide. There were 3 replicates of each treatment. **No. of plants surviving 30 days after treatment.** The LD50 was calculated for each of the herbicides and presented below in the table. Datasets for the meta-analysis are each of the herbicides.							
Outcomes used within systematic review meta-analysis		**Concentration ppm**						
	Treatment	**LD50 ppm**	**1**	**4**	**16**	**64**	**256**	**1000**	**4000**
	2,4-D	**35**	**8.3**	**9.6**	**9.3**	**7.3**	**3.3**	**0.0**	**0.0**
	MCPA	**200**	**10.0**	**9.6**	**10.0**	**9.6**	**4.0**	**0.6**	**0.0**
	Asulam	**16000**	**10.0**	**10.0**	**10.0**	**10.0**	**9.6**	**7.0**	**7.0**
	2,4-D & MCPA	**200**	**10.0**	**10.0**	**9.6**	**9.6**	**4.6**	**0.0**	**0.0**
	2,4-D & Asulam	**230**	**10.0**	**9.6**	**10.0**	**9.6**	**4.0**	**1.3**	**0.0**
	MCPA & Asulam	**380**	**10.0**	**10.0**	**10.0**	**10.0**	**6.0**	**2.6**	**0.0**
	All 3 herb.	**380**	**9.6**	**10.0**	**10.0**	**9.6**	**7.0**	**0.0**	**0.0**
	Control	**N/A**	**10.0**						
Study design	Control Trial **60pts**							
Baseline comparison	Altitude and soil type is unknown; All other comparators are known and are similar. **4pts**							
Intra treatment variation	Again altitude is unknown, other comparators are known and are similar. **3pts**							
Measurement of intervention and co-interventions	Experiment is even, there are no other co-interventions. **2pts**							
Replication & parameter of abundance	Original experiment was replicated 3 times. Parameter of abundance is objective. **4pts**							
Attrition bias	No losses to follow-up. **2pts**							
Data Quality Score Total	**Dataset**	**A-G**						
	Pts	**75**						
Other data presented in study however **not used** in review meta-analysis	<u>Experiment 1 – Effect of 2,4-D, MCPA, Asulam and mixtures on the germination of ragwort seeds.</u> Seeds of *S. jacobaea* were collected from Midmar, Aberdeenshire in autumn 1973. 20 seeds were placed in each of the 150 petri dishes on filter paper soaked with 5ml of herbicide solution. Each herbicide was used at concentrations of 1, 4, 16, 64, 256, 1000, 4000 ppm. Results are in **% germination**.							

Associated Outcomes		Concentration ppm						
	Treatment	1	4	16	64	256	1000	4000
	2,4-D	88.3	86.7	63.3	51.7	6.7	0.0	0.0
	MCPA	76.7	81.7	53.3	20.0	0.0	0.0	0.0
	Asulam	93.3	81.7	91.7	90.0	100.0	76.7	50.0
	2,4-D & MCPA	85.0	80.0	61.7	56.7	8.3	0.0	0.0
	2,4-D & Asulam	90.0	81.7	60.0	45.0	25.0	5.0	0.0
	MCPA & Asulam	76.7	93.3	81.7	53.3	11.7	0.0	0.0
	All 3 herb.	81.7	73.3	40.0	16.7	3.3	1.7	0.0
	Control	90						
Other data presented in study however **not used** in review meta-analysis	<u>Experiment 2 – Effect of 2,4-D, MCPA, Asulam and mixtures of these herbicides on mortality to ragwort root cuttings.</u> Roots of young ragwort plants were detached and thoroughly washed. Roots 1-4mm in diameter were cut into 2cm sections. Ten cuttings at random were placed in each of the 285 petri dishes, on filter paper soaked with 10ml of herbicide solution. Concentrations ranged from 0.001 to 4000 ppm. Cuttings left in the solution for 30 days. Results presented as **Av. No. of root cuttings killed per Petri dish.**							
Associated Outcomes		Concentration in ppm						
	Treatment	0.001	0.004	0.016	0.064	0.256		
	2,4-D	0.00	1.00	0.00	1.00	0.00		
	MCPA	0.00	0.33	0.00	0.00	3.19		
	Asulam	0.00	0.00	0.00	0.00	0.66		
	2,4-D & MCPA	1.33	0.33	1.33	0.00	6.00		
	2,4-D & Asulam	0.00	0.00	0.00	0.00	1.33		
	MCPA & Asulam	0.00	0.00	0.00	0.00	2.33		
	All 3 herb.	1.00	1.33	1.66	3.00	10.00		
		Concentration in ppm						
	Treatment	1	4	64	256	1000	4000	
	2,4-D	10.00	10.00	10.00	10.00	10.00	10.00	
	MCPA	10.00	10.00	10.00	10.00	10.00	10.00	
	Asulam	0.00	0.00	0.00	3.00	1.66	10.00	
	2,4-D & MCPA	10.00	10.00	10.00	10.00	10.00	10.00	
	2,4-D & Asulam	6.33	10.00	10.00	10.00	10.00	10.00	
	MCPA & Asulam	5.00	10.00	10.00	10.00	10.00	10.00	
	All 3 herb.	10.00	10.00	10.00	10.00	10.00	10.00	
Other notes								

Study 29	Taylor, R. L. (1973)	
Methods	A report on 15 trials spanning 5 years, investigating different control methods for ragwort infestations.	
Population	Size of experimental area:	Varies
	Habitat:	Permanent pasture.
	Location:	New Zealand, Motucka & Aorere valleys.
	Altitude:	Unknown
	Plant age at time of treatment:	Various ages, old mature plants with large root stocks selected for many of the trials.
	Soil type:	Fertile river silts.
Intervention & Comparator	**No data to be meta-analysed**	
Outcomes used within systematic review meta-analysis	**No data to be meta-analysed**	
Other data presented in study however **not used** in review meta-analysis	<u>Spot spraying</u> Ragwort was spot sprayed in early spring in 5 trials and in late autumn in 3. MCPA, 2,4-D amine, mecoprop & dichlorprop were used alone at 0.2% concentration, and at 0.15% when combined with dicamba 0.025%. Roots dug up a month after spraying showed effects to a greater depth when dicamba was used, but all plants died. At flowering time MCPA, 2,4-D amine, mecoprop and dichlorprop gave only fair control, which was improved by the addition of dicamba. Emulsifiable free acid of dicamba was superior to the amine.	
Other data presented in study however **not used** in review meta-analysis	<u>Overall spraying</u> Was done to stimulate boom-spraying at 200 l/ha. Three trials treated in early spring gave much better control than 3 done at flowering. 2,4-D amine was superior to MCPA on both young and old plants. In 1 trial sprayed in July, 2,4-D amine at 1.0 kg/ha killed **100%** of ragwort plants, 2,4-DB at 2.0 kg/ha killed **90%** and MCPA at 1.0 kg/ha gave **80%** control. Diacmba killed young plants at 0.1 kg/ha and old plants at 0.5 kg/ha. It improved the control of old plants when added to MCPA or 2,4-D, but at the expense of clover damage. Dichlorprop & mecoprop gave poor control of old ragwort plants 1 to 2 kg/ha with severs damage to white clover, especially mecoprop. 2,4-D amine suppressed white clover less than MCPA.	
Other data presented in study however **not used** in review meta-analysis	<u>Granules spot applied</u> In 2 trials of granules of picloram (2% W/W) or of dicamba (2.5% W/W) killed all plants, but granules of 2,4-D (5% W/W) did not. 70mm of rain fell the night following 2,4-D treatment. Picloram killed ragwort more quickly than dicamba & gave the impression that 2% W/W is an unnecessarily high concentration for ragwort growing on silt. Hemlock (*Conium maculatum*) plants were killed by granules of picloram but not by granules of dicamba or 2,4-D.	
Other data presented in study however **not used** in review meta-analysis	<u>Granules broadcast</u> In 6 trials granules were broadcast with generally disappointing results. Picloram at 0.3 kg/ha gave complete control in 1 trial followed by very heavy rain and flooding, but poor control in 2 other trials. Dicamba at 0.5 kg/ha and 2,4-D at 2 kg/ha gave poor control in all trials, but better where granules were applied to wet foliage. Clover damage from picloram was severe, from dicamba moderate and from 2,4-D light especially when ragwort was treated dry.	
Other notes		

Study 30	Thompson, A. (1974)				
Methods	A series of experiments on the effectiveness of 2,4-D and mixtures on the control of ragwort. The mature ragwort experiment is used for the meta-analysis.				
Population	Size of experimental area:		Unknown		
	Habitat:		Diary pastures		
	Location:		New Zealand, Whakamaru & Paeroa		
	Altitude:		Unknown		
	Plant age at time of treatment:		Mature – (multi-crowned)		
	Soil type:		Pumice soil (Whakamaru) Clay soil (Paeroa)		
Intervention & Comparator	Treatments of 2,4-D alone and in mixtures with picloram and dicamba were compared against each other and no treatment. Single applications in October 1972 or combined with an additional June 1973 application were compared. Results are presented as % recovery of treated mature ragwort, these were converted to % control of mature ragwort to allow uniformity of the data for meta-analysis. The two sites are combined for the meta-analysis. Follow-up January 1974.				
Outcomes used within systematic review meta-analysis	**Treat (kg/ha)**		**Site**		
	Oct 1972	**June 1973**	**Whakamaru**	**Paeroa**	**Mean**
	2,4-D (1.5)	**-**	**92**	**85**	**88.5**
	2,4-D (0.8) picloram (0.2)	**-**	**100**	**93**	**96.5**
	2,4-D (1.2) dicamba (0.3)	**-**	**81**	**82**	**81.5**
	2,4-D (1.5)	**2,4-D (0.6)**	**91**	**99**	**95**
	2,4-D (0.8) picloram (0.2)	**2,4-D (0.6)**	**100**	**100**	**100**
	2,4-D (1.2) dicamba (0.3)	**2,4-D (0.6)**	**96**	**100**	**98**
		2,4-D (0.6)	**64**	**100**	**82**
	Control		**0**	**0**	**0**
Study design	Control Trial **60pts**				
Baseline comparison	All comparators known and similar expect for altitude & size of experimental area. **4pts**				
Intra treatment variation	All comparators known and similar expect for altitude. **3pts**				
Measurement of intervention and co-interventions	No other co-interventions being undertaken. **2pts**				
Replication & parameter of abundance	Unknown replication in the original study. **0pts**				
Attrition bias	No losses to follow-up. **2pts**				
Data Quality Score Total	**71pts**				
Other notes	When 2,4-D was used alone the % clover cover and dry matter production was not significantly affected. In combination with of herbicides there was a significant reduction of clover cover and dry matter production.				

Study 31	Thompson, A. (1977)						
Methods	A timeseries experiment of the effects of spot treatment for the control of ragwort.						
Population	Size of experimental area:			Individual plants (12 plots)			
	Habitat:			Pasture			
	Location:			New Zealand, Morrinsville & Kiwitahi			
	Altitude:			Unknown			
	Plant age at time of treatment:			Rosettes 41-45cm diameter			
	Soil type:			Clay based (Morrinsville) Free draining silt loam (Kiwitahi)			
Intervention & Comparator	**No data to be meta-analysed**						
Outcomes used within systematic review meta-analysis	**No data to be meta-analysed**						
Other data presented in study however **not used** in review meta-analysis	Spot treatment On 26th September 1974, picloram (2.5g/plant); dicamba (4.0g/plant); chlorthiamid (2.0g/plant); dichlobenil (2.0g/plant); 2,4-D (10.0g/plant) & asulam (4kg/1200 litres to run-off) were applied to individual ragwort plants on two sites. The trial areas were divided into 12 plots and 2 plots at each site was allocated to each herbicide. 10 random plants on each plot (20/treatment) were pegged to observe.						
Associated Outcomes		Morrinsville			Kiwitahi		
	Treatment	% knockdown	Time in weeks	% plants flower	% knockdown	Time in weeks	% plants flower
	picloram	99	9	2	99	7	2
	dicamba	70	13	24	82	13	15
	chlorthiamid	99	6	4	99	5	5
	dichlobeni	91	8	8	95	8	7
	2,4-D	84	9	14	88	9	9
	asulam	84	12	14	90	12	11
Other notes							

Study 32	Thompson, A. (1980)			
Methods	A control study of ragwort control within pasture in New Zealand			
Population	Size of experimental area:		25 x 8 m plots	
	Habitat:		Pasture	
	Location:		New Zealand,	
	Altitude:		Unknown	
	Plant age at time of treatment:		All ages	
	Soil type:		Unknown	
Intervention & Comparator	The trial site was divided into 2 blocks, one used in 1976 the other 1977. The larger 2nd block was left untreated in 1976 and an untreated plot was also left for 1979. Each treatment of 2,4-D butoxy ethanol ester was replicated 4 times with 2 untreated controls in each block. Results were presented as % surviving rosettes; these were converted to control of rosettes.			
Outcomes used within systematic review meta-analysis	**Dose**	**Date**	**Treat mean**	**Control**
	0.75	**May 76**	**58**	**92**
	0.75	**May 77**	**81**	**77**
	0.75	**Oct 77**	**92**	**77**
	1.5	**May 77**	**95**	**77**
	1.5	**Oct 76**	**87**	**92**
	1.5	**Oct 77**	**96.5**	**77**
Study design	Control Trial			**60pts**
Baseline comparison	Soil type and Altitude are unknown, all other baseline comparators known and suitably similar.			**4pts**
Intra treatment variation	Again altitude is unknown; all others are known and similar.			**3pts**
Measurement of intervention and co-interventions	Experiment was evenly balanced with no co-interventions.			**2pts**
Replication & parameter of abundance	Well replicated original experimental design (4 replicates).			**4pts**
Attrition bias	No losses to follow-up.			**2pts**
Data Quality Score Total				**75pts**
Other notes				

Study 33	Thompson, A. (1983)				
Methods	Randomised control trials of the use of 3 herbicides applied by a rope wick applicator against 6 weed species, one of which was ragwort.				
Population	Size of experimental area:	4 x 30 m plots.			
	Habitat:	Pasture			
	Location:	New Zealand, Hamilton.			
	Altitude:	Unknown			
	Plant age at time of treatment:	See below			
	Soil type:	Unknown			
Intervention & Comparator	During 1982/83 glyphosate (Roundup 1:2 in water); 2,4-D/picloram (Tordon 50-D 1:1) and 2,4-D/dicamba (Dicambone 75D 1:1). Herbicides applied with a double pass in opposite directions at a speed of 3 km/h using a Winstones 2m wide boom fitted with adjustable flow wicks. Trials laid out as randomised blocks with 4 replicates of each treatment. Rain did not affect the trials. The % surviving is converted into **No. surviving**.				
Outcomes used within systematic review meta-analysis		**Glyphosate A**	**2,4-D/ Picloram B**	**2,4-D/ Dicamba C**	**Untreated**
	Inflorescences	**32.94**	**30.74**	**35.87**	**2196**
Study design	RCT **80pts**				
Baseline comparison	Soil type and Altitude are unknown, all other baseline comparators known and suitably similar. **4pts**				
Intra treatment variation	Again altitude is unknown; all others are known and similar. **3pts**				
Measurement of intervention and co-interventions	Experiment was evenly balanced with no co-interventions. **2pts**				
Replication & parameter of abundance	Well replicated original experimental design (4 replicates). **4pts**				
Attrition bias	No losses to follow-up. **2pts**				
Data Quality Score Total	**Datasets**	**A-C**			
	Pts	**95**			
Other notes					

Study 34	Thompson, A. & Saunders, A. (1984)									
Methods	A randomised control trial of 2,4-D and MCPA, alone and in combination for the control of ragwort.									
Population	Size of experimental area:						20 x 3 m plots			
	Habitat:						Pasture			
	Location:						New Zealand			
	Altitude:						Unknown			
	Plant age at time of treatment:						All ages			
	Soil type:						Unknown			
Intervention & Comparator	All sites were cattle grazed with the exception of one. In all trials the treatment was replicated four times in randomised blocks, the means of these have been combined for the meta-analysis. Herbicides were applied in 250 l/ha water through a CO_2 pressure sprayer and hand boom at 210 kPA. Follow-up was Feb/March 1984. Herbicide concentrations were as follows:									
	Total kg ai/ha	**0.9**			**1.4**			**1.8**			**Control**
	2,4-D/ MCPA ratio	**1:0**	**1:1**	**0:1**	**1:0**	**1:1**	**0:1**	**1:0**	**1:1**	**0:1**	**0**
	2,4-D	**0.9**	**0.45**	**-**	**1.35**	**0.68**	**-**	**1.80**	**0.90**	**-**	**-**
	MCPA	**-**	**0.47**	**0.94**	**-**	**0.70**	**1.40**	**-**	**0.94**	**1.87**	**-**
Outcomes used within systematic review meta-analysis	**Total kg ai/ha**	**0.9**			**1.4**			**1.8**			**Control**
	2,4-D/ MCPA ratio	**1:0**	**1:1**	**0:1**	**1:0**	**1:1**	**0:1**	**1:0**	**1:1**	**0:1**	**0**
	% reduction in flowering plants	**74.4**	**63.4**	**49.4**	**84.4**	**80.2**	**65**	**90.2**	**84.4**	**72.6**	**2.28**
Study design	RCT **80pts**									
Baseline comparison	Soil type and Altitude are unknown, all other baseline comparators known and suitably similar. **4pts**									
Intra treatment variation	Again altitude is unknown; all others are known and similar. **3pts**									
Measurement of intervention and co-interventions	Experiment was evenly balanced with no co-interventions. **2pts**									
Replication & parameter of abundance	Well replicated original experimental design (4 replicates). **4pts**									
Attrition bias	No losses to follow-up. **2pts**									
Data Quality Score Total	**Dataset**						**A-C**			
	Pts						**95pts**			
Other notes	When 2,4-D and MCPA were combined the effect was additive, not synergistic, so that a 1:1 tank mix of the 2 gave less effective ragwort control than 2,4-D alone. MCPA was more severe on white clover than 2,4-D. A 1:1 mixture however was at least as severe on clover as 2,4-D which was worse than MCPA.									

Study 35	Thompson, A. & Saunders, A. E. (1986)
Methods	Timeseries data on the effects of fertilisers on ragwort in pasture.
Population	Size of experimental area: Unknown Habitat: Pasture Location: New Zealand, Patetonga; Wharepapa South & Waimiha. Altitude: Unknown Plant age at time of treatment: All ages. Soil type: Clay & pumice soils.
Intervention & Comparator	**No data to be meta-analysed**
Outcomes used within systematic review meta-analysis	**No data to be meta-analysed**
Other data presented in study however **not used** in review meta-analysis	<u>Seedlings & juvenile ragwort</u> Two trials were conducted to measure the effect of phosphate, nitrogen and 2,4-D. At both sites when the trials commenced in spring 1982 the ragwort plants were all small, mainly under 5cm diameter and had germinated in autumn 1982. <u>Established ragwort</u> Two trials as above. In August, 1984 factorial trials of 2 rates of phosphate (0 or 50 kg P/ha) and 3 rates of boom sprayed 2,4-D (1.0, 2.0 or 3.5 kg ai/ha)

Associated Outcomes

	Ragwort plants/100m^2			
Phosphate (kg/ha)	0		70	
Nitrogen (kg/ha)	0	50	0	50
Small plants	388	323	123	128
Established plants	291	329	156	188

Associated Outcomes

	Ragwort plants/100m^2				
Phosphate (100kg/ha)	Nil	Spring	Spring	Spring	Spring
Nitrogen (100kg/ha)	Nil	Nil	Spring	Aut.	Spring & Aut.
No 2,4-D	204	107	47	130	58
2,4-D 1.5kg ai/ha	-	16	7	-	6
2,4-D 1.5kg ai/ha	-	13	5	12	4

Associated Outcomes

		Ragwort plants/100m^2			
		Surviving regrowths		New plants	
		December 1985		April 1986	
2,4-D (kg ai/ha)	Phosphate (kg/ha)	Trial		Trial	
		3	4	3	4
Nil	0	-		185	174
Nil	100	-		129	73
1.0	0	40	24	20	48
1.0	100	51	37	14	34

Other notes	

Study 36	Watt, T. A. (1984)					
Methods	A series of experiments to investigate the use of fertiliser and herbicide in combination to control ragwort.					
Population	Size of experimental area:			3 x 3 m plots		
	Habitat:			Perennial ryegrass sward		
	Location:			U.K., Oxford University Field Station, Wytham.		
	Altitude:			Unknown		
	Plant age at time of treatment:			From seed		
	Soil type:			Unknown		
Intervention & Comparator	**No data to be meta-analysed**					
Outcomes used within systematic review meta-analysis	**No data to be meta-analysed**					
Other data presented in study however **not used** in review meta-analysis	The main plot treatments were 4 combinations of presence and absence of propyzamide with high and low fertiliser. Propyzamide was applied at 0.4 kg ai/ha. Within each of the main plots were 6 sub-plots. These were stratified random positions within the central 1.5 x 1.5m of the main plot, at each of which a gap was made in the sward by removing root and shoot material. Ten seeds of *S. jacobaea* were sown just below the surface in the central 5cm circle of each gap, using a template which placed 7 in an outer ring and 3 in the middle.					
Associated Outcomes	No. of plants per gap on 2-4th June as a % of the seed sown					
		Without propyzamide	With propyzamide	Mean		
	Low fertiliser	51.0	50.1	50.5		
	High fertiliser	45.9	59.2	52.5		
	Mean	48.4	54.6			
	The No. of leaves on the ragwort plants in each gap (17th Oct.)					
		With propyzamide fertiliser		Without propyzamide fert.		Total
	Leaf No.	Low	High	Low	High	
	0	9	6	17	21	53
	1 – 6	4	5	13	9	31
	7 +	17	19	0	0	36
	Total	30	30	30	30	120

Study 37	Whitson, T. D., Hawkes, B., Brown, J., Humphrey, D. & Langland, D. (1986)		
Methods	A randomised control trial (RCT) conducted in Linn county, Oregon on the effectiveness of 9 different herbicides for the control of common ragwort.		
Population	Size of experimental area:	3 x 8 m plots	
	Habitat:	Pasture	
	Location:	U.S.A., Linn County, Oregon.	
	Altitude:	Unknown	
	Plant age at time of treatment:	All ages	
	Soil type:	McCully clay loam (pH 6.2).	
Intervention & Comparator	Nine herbicides (see below) are applied at a number of different dose levels for their control against ragwort. The plots were replicated 4 times in a randomised complete block design. Herbicides were applied in a pasture at 40psi and 151.6 l/H_2O with a boom sprayer. Data of each year is combined for the meta-analysis. Data is presented in **% Control**, follow-up 3 months.		
Outcomes used within systematic review meta-analysis	**Treatment**	**Rate (kg ai/ha)**	**% control**
	Clopyralid	**0.045**	**66**
	Clopyralid	**0.090**	**82**
	Clopyralid	**0.180**	**96.5**
	Chlorsulfuron	**0.008**	**93.5**
	Chlorsulfuron	**0.017**	**95**
	Chlorsulfuron	**0.025**	**97**
	Chlorsulfuron	**0.034**	**100**
	Metsulfuron	**0.008**	**99**
	Metsulfuron	**0.017**	**100**
	Metsulfuron	**0.025**	**100**
	Metsulfuron	**0.034**	**100**
	Dicamba	**0.045**	**23**
	Dicamba	**0.090**	**63**
	Dicamba	**0.135**	**57**
	2,4-D ester	**0.135**	**87**
	2,4-D ester	**0.270**	**95.5**
	2,4-D ester	**0.360**	**96.5**
	2,4-D amine	**0.135**	**57**
	2,4-D amine	**0.270**	**93.5**
	2,4-D amine	**0.360**	**97**
	triclopyr	**0.135**	**42.5**
	triclopyr	**0.270**	**61.5**
	triclopyr	**0.360**	**69**
	picloram	**0.045**	**99**
	picloram	**0.090**	**100**
	picloram	**0.180**	**100**
	Dicamba + 2,4-D	**0.045 + 0.135**	**91.5**
	Dicamba + 2,4-D	**0.090 + 0.270**	**93.5**
	Triclopyr + 2,4-D	**0.023 + 0.045**	**47.5**
	Triclopyr + 2,4-D	**0.045 + 0.090**	**75**
	ALL CONTROLS	**0**	**0**
Study design	RCT **80pts**		
Baseline comparison	Altitude is unknown, all other baseline comparators known and suitably similar. **5pts**		

Intra treatment variation	Again altitude is unknown; all others are known and similar. **3pts**
Measurement of intervention and co-interventions	Experiment was evenly balanced with no co-interventions. **2pts**
Replication & parameter of abundance	Well replicated original experimental design (4 replicates). **4pts**
Attrition bias	No losses to follow-up. **2pts**
Data Quality Score Total	**96pts**
Other notes	Treatments of metsulfuron-methyl and chlorsulfuron caused grass browning for approx. 30 days following treatment, but only slightly caused grass height reduction. Small hop clover and white clover stand reductions were observed from applications of clopyralid, chlorsulfuron, metsulfuron, dicamba and picloram. pH of the soil was 6.2

Study 38	Woodcook, J. W. (1936)	
Methods	Timeseries data comparing ragwort control with “atlacide” (old & new formula) as compared with sodium chlorate.	
Population	Size of experimental area:	Unknown
	Habitat:	Various farm fields
	Location:	New Zealand
	Altitude:	Unknown
	Plant age at time of treatment:	All ages
	Soil type:	Unknown
Intervention & Comparator	**No data to be meta-analysed**	
Outcomes used within systematic review meta-analysis	**No data to be meta-analysed**	
Other data presented in study however **not used** in review meta-analysis	Five farms were used in 1935. Treatments included applications of 1%, 3% & %% solution of “Atlacide” and sodium chlorate respectively and also these materials applied in the dry state mixed with carbonate of lime in 2 different proportions – 2 parts specific to 98 parts lime and 5 parts specific and 95 parts lime.	

Associated Outcomes

		% kill in various trials				
Specific	Conc. or mix	Te Kuiti	Te Kuiti	Tawhiti	Waianiwa	Tisbury
Sodium chl.	1%	83	99.5	100	100	No spray treat ments
Atlacide	1%	65	99	100	100	
Sodium chl.	3%	99	100	100	100	
Atlacide	3%	88	100	100	99	
Sodium chl.	5%	99	100	100	100	
Atlacide	5%	96	100	100	100	
Sodium chl.	2 to 98 lime	90	100	100	No dust treat-ments	98.6
Atlacide	2 to 98 lime	61	99	100		97.5
Sodium chl.	5 to 95 lime	92	100	100		99.4
Atlacide	5 to 95 lime	92	100	100		99.1

Other data presented in study however **not used** in meta-analysis	As the manufacturers of “Atlacide” intended adopting a new an improved formula another nine experiments in which new material was used. Trials undertaken in autumn 1936.

Associated Outcomes

	% of sprayed plants killed					
	3% solution		5% solution		Lime 95% Specific 5 %	
	Atlacide	Sod. Chl.	Atlacide	Sod. Chl.	Atlacide	Sod. Chl.
Kopaki	91.5	96.0	93	96	78	87
Rotorua	93.4	99.1	97	99.6	60.3	88.6
Rotorua	92.5	97.7	99.5	95.9	94.2	94.2
Mamaku	100	-	100	100	100	100
Mamaku	89	-	87.8	93.3	-	-
Te Awamutu	-	-	-	-	100	100

Appendix 3. Methodology for missing measures of variance

- For "All data" missing standard deviations (sd), when n=1 the following procedure was undertaken.

    1. n +1 (n needs to be larger than 1 to allow for an sd and comparison)

    2. Take largest sd from the arm looking at i.e. treatment or control (If don't have an sd value for arm looking at then use the other arms largest sd.

    3. Double this value to allow for possible worse case scenario.

- When both the treatment and control is n=2+ and both sd's are 0 then both the sd's are changed to 0.5 to allow for comparison within StatsDirect.

- All values derived from above are kept for the entire analysis.

Appendix 4. Additional Single Herbicide Results

The pooled effect size, 95% confidence intervals (CI) and DerSimmonian-Laird chi-squared significance (sign) are presented. Results for mortality data are positive for a treatment effect (i.e. the herbicide application increases mortality). For population density data results are negative for a treatment effect (the herbicide application reduces the population density of ragwort species). Not required in the box = original meta-analysis was performed on independent data. Dashes represent when no data was available. In all cases the meta-analyses were performed on only *S. jacobaea* datasets.

		Known Data			All Data		
Herbicide		Independent Data	Positive Sen. An	Negative Sen. An	Independent Data	Positive Sen. An	Negative Sen. An
Mortality Data – *S. jacobaea* Only							
2,4-DB	**n** **Effect Size** **95% CI** **sign.**	-	-	-	3 2.29 0.96 to 3.63 p = 0.0007	-	-
Chlorsulfuron	**n** **Effect Size** **95% CI** **sign**	3 12.98 3.64 to 22.31 p = 0.0064	-	-	-	-	-
Flazasulfuron	**n** **Effect Size** **95% CI** **sign**	-	3 23.73 -0.43 to 47.88 p = 0.0231	3 5.84 0.61 to 11.07 p = 0.043	-	6 4.42 0.61 to 8.24 p = 0.0231	6 2.10 0.07 to 4.14 p = 0.043
Metasulfuron	**n** **Effect Size** **95% CI** **sign**	4 84.08 50.42 to 117.74 p < 0.0001	-	-	-	-	-
Picloram	**n** **Effect Size** **95% CI** **sign**	3 80.95 40.01 to 121.89 p = 0.0001	-	-	-	5 30.91 8.64 to 53.18 p = 0.0065	5 31.08 8.35 to 53.82 p = 0.0074
Triclopyr	**n** **Effect Size** **95% CI** **sign**	3 6.97 1.34 to 12.60 p = 0.0153	-	-	-	-	-
Population Density Data – *S. jacobaea* Only							
Glyphosate	**n** **Effect Size** **95% CI** **sign.**	-	-	-	-	6 -8.78 -14.34 to -3.23 p = 0.0019	6 -8.62 -14.04 to -3.19 p = 0.0019
Dichlorprop	**n** **Effect Size** **95% CI** **sign.**	-	-	-	6 -0.16 -0.93 to 0.61 p = 0.6807	-	-
Mecoprop (CMPP)	**n** **Effect Size** **95% CI** **sign.**	-	-	-	5 -0.34 -1.23 to 0.54 p = 0.4471	-	-