Management and Control of Greater Bindweed (*Calystegia silvatica*) in Riparian Margins in New Zealand

Julia Wilson-Davey, Trevor James and Anis Rahman

Landcare Research
Manaaki Whenua

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Julia Wilson-Davey [1], Trevor James [2] and Anis Rahman [2]

[1] Landcare Research
PO Box 40, Lincoln 7640
New Zealand

[2] AgResearch
Private Bag 4749, Christchurch 8140
New Zealand

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Reviewed by:	Approved for release by:
Quentin Paynter Scientist Landcare Research	Matt McGlone Science Leader Biodiversity and Conservation

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Summary

Project and Client

Gisborne District Council asked Landcare Research to investigate the methods used to control greater bindweed (*Calystegia sylvatica*) from the literature and make suggestions for its control and possible future research to improve control methods. Greater bindweed (also called convolvulus) is a significant threat to the successful establishment and survival of native plants in riparian margins in parts of the North Island. AgResearch have provided all the information in this report on conventional control methods. This work was carried out in 2009 with an Envirolink Medium Advice Grant from the Foundation for Research, Science and Technology.

Objectives

- Carry out a literature review on research undertaken nationally or internationally on control and management options for greater bindweed.
- Carry out a literature review on control options for related plant species, such as pink bindweed, old man's beard and muehlenbeckia.
- Provide an overview of control options, particularly in wetlands or newly planted riparian margins.
- Outline risks of bindweed control to associated native plant species and the species currently being promoted for riparian planting.
- Provide recommendations for field trials and further research into control options.

Recommendations

- Based on the research already conducted in New Zealand and other countries on *Calystegia* spp. and similar problem perennial weeds, below are some suggestions for research into controlling/managing this weed in riparian margins.

Chemical control

- Glyphosate is a potential herbicide tool available for use in riparian margins. However, due to the risks involved with this chemical, specific research is required regarding appropriate rates, timing, methods of application, adjuvants, and formulation. Detailed investigations should be undertaken on mitigating damage risks to riparian species and associated native plants.
- The hormone herbicides (including MCPB, MCPA, 2,4-D, dicamba, triclopyr and the new herbicide aminopyralid) are potential options as most of the riparian margins are associated with common pasture species (grasses and legumes). AgResearch has considerable information on use of these materials in pasture. Research questions would relate to how these chemicals could be fitted into the riparian margins and in particular the safety of aminopyralid on native species.
- Fluroxypyr appeared useful on some other invasive vines that lacked hard, woody stems. It could be worth evaluating on young *C. silvatica* especially as damage to non-target species could be less compared with other herbicide options.
- Amitrole may have a place in limited situations and could be worth investigating where riparian species used may have some tolerance to this herbicide.

- Metsulfuron-methyl is likely to also be effective on *C. silvatica* but would also severely damage non-target woody species and therefore not be recommended.
- Investigations on minimising/mitigating potential risks to non-target species should be undertaken.

Integrated management

- From the literature and AgResearch's research on managing weeds in orchards, there appears to be an opportunity to exploit the suppressive effect of suitable ground cover species. Dense-growing native species, such as rice grass (*Microlaena stipoides*) and toetoe (*Cortaderia* spp.), would be best but vigorously growing herbs such as *Lotus pedunculatus* and creeping buttercup (*Ranunculus repens*) may be able to provide some suppression in the short term. It could also be worth investigating ways of enhancing the suppressing ability of Yorkshire fog (*Holcus lanatus*) as it is densely-growing and very common in riparian situations. The competitive ability of the ground cover species can be supplemented with low rates of MCPB, glyphosate or paraquat.

Biological control

- *Calystegia silvatica*, greater bindweed, is likely to be a difficult target for biocontrol in New Zealand. The natural enemies of this species have not been specifically studied. Such surveys are likely to cost $100,000–$200,000 and may not reveal any suitable potential biocontrol agents. The natural enemies of close relatives, that have been well studied, tend to be oligophagous (feed on several hosts). A biocontrol agent for *C. silvatica* in New Zealand would need to be highly specific as attack on native *Calystegia* and *Convolvulus* species would be unacceptable.
- Mycoherbicides could potentially be used to control *C. silvatica* in New Zealand but may not be practical for several reasons. None of the three fungi that have been developed as mycoherbicides overseas occur in New Zealand. As they would be new organisms under the Hazardous Substances and New Organisms (HSNO) Act 1996, permission would need to be gained from the Environmental Risk Management Authority (ERMA). Trials would need to be undertaken before such an application could be made to assess the suitability of introducing these fungi into New Zealand. The cost of this research and obtaining ERMA approval, if they were in fact suitable, is likely to be $300,000–$500,000. A source of the fungal species would need to be identified, and if it is not available in mycoherbicide form there is the added work and cost to produce it. Overall this would not be a cheap option.

1 Introduction

Land development and associated vegetation clearance has resulted in the transformation of natural ecosystems along riparian margins to predominantly pasture. Riparian margins and their vegetation perform an important role in maintaining and enhancing water quality and providing habitat in these ecosystems. They are important for preventing streambank erosion, reducing flood flows, removing nutrients and sediment, and for terrestrial and aquatic fauna. Consequently, regional councils have invested significant resources into riparian revegetation programmes to help landowners mitigate the effects of intensive land use on water quality and loss of indigenous vegetation.

New Zealand' s National Biodiversity Strategy identifies Land Environments of New Zealand at Level IV that have 20% or less remaining in indigenous cover as a national priority. Also, improving water quality from the effects of dairy farming by implementing good riparian management has been given national importance through the Dairying and Clean Streams Accord. These combined benefits of improving water quality and enhancing biodiversity have been used to encourage landowners to implement riparian management and restoration.

Calystegia silvatica or greater bindweed (also called convolvulus) is a significant threat to the successful establishment and survival of native plants in riparian margins. Fenced-off riparian margins can provide corridors for greater bindweed to spread, smother, and kill newly established plantings within 2–3 years. It is well established and widespread throughout New Zealand and is most commonly found growing in farm hedges, in wetlands, in riparian sites next to waterways, and is prevalent along the railway corridors.

Landowners will be required to commit significant financial resources to implement riparian fencing around plantings over the next few years to meet the targets under the Clean Streams Accord. Some individual farms have up to 10 km of waterways to fence and plant, which could cost up to $50,000. If greater bindweed spreads into riparian margins, individual landowners do not have the knowledge or capacity to control or manage large infestations during the establishment phase.

Greater bindweed has an extensive underground rhizome that can extend several metres and has the capacity to resprout and reinvade sites when the foliage is removed. It is also a serious threat to the revegetation of wetlands or bush remnants that is being promoted by most regional councils. There has been little investigation in New Zealand on control and management options of this weed.

Gisborne District Council asked Landcare Research to investigate the methods used to control greater bindweed from the literature and make suggestions for its control and possible future research to improve control methods. AgResearch have provided all the information in this report on conventional control methods. This work was carried out in 2009 with an Envirolink Medium Advice Grant from the Foundation for Research, Science and Technology.

2 Objectives

- Carry out a literature review on research undertaken nationally or internationally on control and management options for greater bindweed.
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- Provide an overview of control options, particularly in wetlands or newly planted riparian margins.
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3 Methods and Data Sources

Literature searches for information about chemical and mechanical methods of control were conducted of primary databases, namely CAB, BIOSIS, Index New Zealand and Te Puna (National Bibliographic Database). A search of the general Web was also made, and a number of government and research websites were used to retrieve statistical data. These included Weeds Australia database, Noxious Weeds list, http://www/weeds.org.au/noxious.htm; Biosecurity NZ regional pest management http://www.biosecurityperformance.maf.govt.nz/public/TableReport.aspx; and Invasive plants of the United States http:///www.invasive.org/weeded/index.htm. Search terms covered the chemical or mechanical control of *Calystegia silvatica* plus synonyms and common names (Appendix 1). *Calystegia sepium* was also used as a search term but results were restricted to its occurrence in orchards, vineyards and forests. A further 21 invasive vines plus common names were identified for an additional search. Three New Zealand plants (*Calystegia soldanella*, *Calystegia tuguriorum* and *Muehlenbeckia australis*) were checked in the literature databases and on New Zealand government and local government websites.

Literature searches for information on biological control were conducted of electronic databases CAB Abstracts, Current Contents, ISI Proceedings, and Web of Science. Initial search terms included *Calystegia silvatica*, *Calystegia*, greater bindweed, bindweed/s, and biological control / biocontrol. Additional search terms included *Calystegia sepium*, *Convolvulus arvensis*, and *Convolvulus*. A search of the general Web using Google's search engine was also made. Further literature was found by searching the references listed in the relevant papers sourced.

4 Main Findings

4.1 Chemical and mechanical control

Results of search on *Calystegia silvatica*

Very little work has been done on control options for *Calystegia silvatica* as this species does not appear to have wide distribution on an international scale. Of the three references found (See Appendix 2), one is an AgResearch study conducted in Waikato in the 1990s. The other two reports are from UK research conducted in the 1950s and include herbicides that are no longer available (Table 1).

In the UK studies regular cultivation was reported to prevent seeding and in time weaken the plant, but did not provide sustainable long-term control. Treatment with 2,4-D on the young regrowth resulted in short-term damage. Similarly in AgResearch's experiments, triclopyr, dicamba, glyphosate, chlorsulfuron and amitrole all provided good weed knockdown, but regrowth soon occurred. Clopyralid was ineffective. The only herbicide that showed long-term efficacy, with effects lasting through to the following season, was the persistent herbicide imazapyr at rates of 0.5–1 kg/ha.

Table 1 Chemical control options for *Calystegia silvatica* (summary of literature review)

Herbicide active ingredient	Rate kg/ha	Level of control	Reference[1]
2,4-D amine	1.6–2.2	Short-term control of young regrowth	3
2,4-D ester	1.1–1.6	Short-term control of young regrowth	3
2,4-D	3700 ppm	Partial control (≈ 70% less regrowth)	2
Triclopyr	1.2	Good knockdown, considerable regrowth	1
Dicamba	0.4	Good knockdown, considerable regrowth	1
Glyphosate	2.16	Good knockdown, considerable regrowth	1
Chlorsulfuron	0.015	Good knockdown, considerable regrowth	1
Amitrole	4.0	Good knockdown, considerable regrowth	1
Imazapyr	0.5–1.0	Good knockdown, considerable suppression of regrowth in the next season	1
2,4,5-T	No longer available		2

[1]Refer to bibliography in Appendix 2.

Results of search on *Calystegia sepium*

Calystegia sepium (a closely related species to *C. silvatica*) is more prevalent around the world and considerably more research has been done on chemical control of this species. There is also some information on non-chemical control options, including cultivation, which would not be practical in the riparian margins.

The information summarised in Table 2 gives the main chemical options and can be summarised as follows:

Glyphosate

- Only one report suggested excellent control from application rate of 1.2 kg/ha.
- A couple of reports showed good control if applied at budding or flowering stage, but mostly only during the year used.
- Several reports showed good control if used just before flowering of the weed, but only at rates around 3.6–4.5 kg/ha.
- Some reports still showed only moderate control even at these high rates, with regrowth occurring during the same season.
- Some researchers reported good control from the high rates (4.5 kg/ha) but only if applied for 2–3 successive years.
- In summary, glyphosate does have reasonable efficacy on this weed but the rates investigated in the 1960–80s (2 kg and above) are rarely used today. If lower rates are to be investigated, repeat applications would be the only option.

Hormone herbicides

- The phenoxy herbicides MCPB, MCPA, 2,4-D and 2,4,5-T have been widely evaluated for control of *C. sepium* in many arable and horticultural crops where it is often a serious problem.
- MCPB at rates between 1.5 and 3.0 kg/ha has been reported by several workers to provide good control in the year of treatment, when applied late in the season after active growth has ceased.
- MCPA at rates of 1.0–1.5 kg/ha provided moderate control if used at the flowering stage of the weed.
- 2,4-D at rates between 0.8 and 1.5 kg/ha has been found to provide good control by many researchers when used at flowering stage of the weed. The control lasted mostly one growing season only.
- Spot spraying with dicamba provided good control in spring to early summer when the weed is in full leaf.

Other herbicide options

- Amitrole has been used with some success in many horticultural situations.
- A number of other residual herbicides are reported to have varying levels of efficacy on *C. sepium*. These are all used in horticultural or non-crop situations and would not suit the riparian margins.
- Some of the herbicides reported to provide good control of this weed are no longer available in New Zealand or internationally.

Non-herbicide options

- Most of the research shows that *Calystegia* spp. plants are difficult to eliminate solely by herbicides.
- One option is to use competitors, preferably desired native species like toetoe (*Cortaderia* spp.), to establish a dense cover of moderate height. A dense cover of low-growing herbs such as lotus (*Lotus* spp.) and creeping buttercup (*Ranunculus repens*) might also inhibit *Calystegia* spp. spread but only in the short term (P. Williams pers. comm.). It could also be worth investigating ways of enhancing the suppressing ability of Yorkshire fog (*Holcus lanatus*) as it is densely-growing and very common in riparian situations. The competitive ability of the ground cover species can be supplemented with low rates of MCPB, glyphosate or paraquat.

- Another option used includes regular cultivation to stop the establishment of the weed in arable and horticultural situations. However, this is not a practical or viable alternative for riparian margins because of obstacles such as plantings and fences.

Table 2 Chemical control options for *Calystegia sepium* (summary of literature review)

Herbicide active ingredient	Rate kg/ha	Level of control	Reference[1]
Glyphosate	2.2–3.3	Poor	7
Glyphosate	3.6–4.5	Good initial control, but considerable regrowth within 3–6 weeks	8, 9
Glyphosate	3.8	Moderate control	13
Glyphosate	4.5	Good control if applied just before flowering of the weed	12, 20, 22, 38
Glyphosate	4.5	Good control	6, 15
	3.6–4.5	Good control with application in 2 successive years before it climbed into trees	14
	4.5	Good control with three applications	5
Glyphosate	2.5	Good control – most effective when applied at budding or flowering stage	16
Glyphosate	2.2	Good control during the year used	18
Glyphosate	1.2	One application gave excellent control	39
MCPB	2.8	Good control if applied late	25,33
MCPB	2.0–3.5	Good control if used late when active growth has ceased	27
MCPB	1.5–2.0	Good control in the year of treatment	11,37
MCPA	1.0	Good control	30, 31, 33
MCPA	1.5	Moderately susceptible if used at flowering stage	41
2,4-D amine	0.8	Good control if used as flowering ends	21
2,4-D amine	1	Good control, cheapest chemical option	20
2,4-D amine	1.1	Some control	26, 32
2,4-D	1.5	Moderately susceptible if used at flowering stage	41
2,4-D	1.5–2.0	Good control in the year of treatment	11, 37
2,4-D + Dalapon	3.4 + 21.25	Good control with two applications	6
Dicamba	Spot spray	Good control if used in spring – early summer when in full leaf	40
Amitrole	4.8	Stunting only	21
Amitrole + simazine	4.8 + 2.0	Good control	24, 28

[1]Refer to bibliography in Appendix 3.

Results of search on related plant species

Literature searches were conducted also on 21 plant species, including weeds closely related to *C. silvatica* as well as unrelated invasive vines. Results of these searches on species of particular relevance to New Zealand are presented in Table 3.

Table 3 Chemical control options for other weedy vines (summary of literature review)

Plant species	Common name	Control options Active ingredient (Trade name)	Reference
Actinidia spp.	Kiwifruit	Triclopyr/picloram (Tordon Brushkiller) Triclopyr (Grazon) Picloram gel (Vigilant)	42
Anredera cordifolia	Madeira vine	Metsulfuron-methyl (various) Triclopyr/picloram (Tordon Brushkiller) Glyphosate (various) Amitrole (various) Fluroxypyr (Starane) Glyphosate – repeated every 3 months	44 45,43
Araujia sericifera	Moth plant	Glyphosate (various) Glufosinate (Buster)	46, 47
Asparagus asparagoides	Bridal creeper	Glyphosate (various) Glyphosate – repeat applications Metsulfuron-methyl (May –July) Metsulfuron-methyl (August – at flowering) Metsulfuron-methyl (low rates but repeat applications) Triclopyr/picloram Note: Most researchers stated that damage to native plants is minimised due to the canopy effect of the weed)	48, 52, 53 49 50, 52, 54 51, 53, 56 55 56
Asparagus africanus	Climbing asparagus	Triclopyr (Grazon) Fluroxypyr (Starane) Glyphosate	57
Cardiospermum grandiflorum	Balloon vine	No references	
Celastrus orbiculatus	Climbing spindle berry	Picloram gel (Vigilant) Triclopyr (Grazon)	57 58
Clematis vitalba	Old man's beard	Atrazine + cyanazine Imazapyr (Arsenal) Glyphosate (various) Picloram gel (Vigilant) Triclopyr + picloram Clopyralid (various)	59 60, 62 60, 62, 63, 64, 65 61, 57 64 64

Plant species	Common name	Control options	Reference
Hedera helix	English ivy	Glyphosate (various)	66
		Glyphosate – considerable regrowth	68
		2,4-D amine – two applications	66
		Growth regulators	67
Lonicera japonica	Japanese honeysuckle	Cutting + glyphosate	69
		Glyphosate	70, 71, 73, 74, 78, 81
		Glyphosate (minimum 2 applications)	76
		Triclopyr	70
		Metsulfuron – methyl	70, 71, 75
		Amitrole	77, 78
		Note: good recovery of native species noted after glyphosate treatment.	70
		Good results from chemical + biological control.	72
Macfadyena unguis-cati	Cat's claw	Glyphosate (repeat spray of regrowth)	79
		Glyphosate – single application not effective	80
Muehlenbeckia australis	Pohuehue	Defoliated by glyphosate, triclopyr, clopyralid and metsulfuron, but often regenerated reasonably well after the death of climbing dock and Japanese honeysuckle.	81

Glyphosate

- Glyphosate is the most widely researched and recommended herbicide product for controlling and managing invasive vines.
- In most cases, repeat applications (at least 2) of glyphosate are needed for satisfactory control.
- Later applications, at flowering or subsequent to flowering, have often provided better results.
- Damage from glyphosate to native plant species is minimised in the case of invasive vines that have ample canopy growth.
- Some researchers noted good recovery of native species after glyphosate treatment, although it required considerable time in many cases.

Hormone herbicides

- Phenoxy herbicides (MCPA, MCPB, 2,4-D) rarely proved useful for control of invasive vines, with the exception of 2,4-D + picloram.
- Picloram and its combinations with triclopyr have been widely evaluated and often provided good control of most invasive vines. Being selective to Graminae species, picloram does offer the advantage of leaving behind some vegetation cover, which helps arrest immediate weed reinvasion. However, it does pose potential damage risks to other desired vegetation (due to its excellent translocation and movement characteristics) and serious environmental risks due to its long persistence and high mobility in the soil. These risks need to be managed carefully.

- The picloram gel formulation (Vigilant) developed by HortResearch has been successfully used for control of many woody vine species. This formulation significantly reduces the environmental risks associated with this chemical as well as the potential for damage to non-target species.
- Triclopyr alone or in combination with picloram has been the most successful product, after glyphosate, for control of these invasive vines.
- Amitrole and fluroxypyr are the other products found useful by some researchers.

Additional potential options for *Calystegia silvatica* based on searches on related invasive vines

- The potential herbicide options, in addition to those listed in Table 1, would include metsulfuron-methyl and possibly fluroxypyr.

4.2 Biological control

Biological control (biocontrol) is a method of control where the natural enemies of an organism are used to control it. Part of the process in choosing a suitable biocontrol agent is to identify how specific it is to the target species. In most cases a natural enemy is chosen that will only attack the target species and this specificity is one of the advantages of using biocontrol. Another is the ongoing pressure the biocontrol agent will exert on the target species once it is established. In the case of weeds, insect, mite and pathogen species have been used as biocontrol agents.

Greater bindweed (*Calystegia silvatica*)

There have not been any attempts to undertake biocontrol of *C. silvatica* anywhere in the world or any studies into its natural enemies. As no specific information was found, the search was broadened to include information about the biocontrol of close plant relatives and a study of the relatedness of these plants was also undertaken and is described below.

Calystegia taxonomic relationships – Convolvulaceae

The genus *Calystegia* belongs to the family Convolvulaceae. The family is dominated by species in the closely related genus *Convolvulus* and in *Ipomoea*, which includes morning glories and *I. batatas*, kumara or sweet potato (Cronquist 1988). Molecular phylogenetic work on Convolvulaceae shows *Calystegia* nested within *Convolvulus* (Stefanović et al. 2002). Because of the closeness of the phylogentic relationship it is proposed that *Calystegia* species should be put in *Convolvulus*, but as a distinct subgenus (Stefanović et al. 2002; S. Wagstaff pers. comm.). However, there has not been any phylogenetic work done on these two genera and so the details of how *Calystegia* species fit amongst *Convolvulus* species are not yet known. The close relationship between the two genera is also reflected by *Calystegia* being considered synonymous with *Convolvulus* in the past (Lewis & Oliver 1965). The Landcare Research New Zealand Plant Names Database (Ngā Tipu o Aotearoa – New Zealand Plants, http://nzflora.landcareresearch.co.nz/, accessed 18 November 2009) also lists *Convolvulus* synonyms for several *Calystegia* species, e.g. *C. silvatica* and *C. sepium*.

Calystegia and *Convolvulus* in New Zealand

New Zealand has three native and two introduced species of *Calystegia* (Webb et al. 1988). Of the native species, shore bindweed (*C. soldanella*) and *C. tuguriorum* are widespread but *C. marginata* is rare (Ogden 1978; Webb et al. 1988). The two introduced species are greater bindweed (*C. silvatica*) and hedge bindweed (*C. sepium*). *C. sepium* is an important weed in eastern North America (Rosenthal 1980; Rosenthal & Buckingham 1982). There are two recognisable forms of *C. sepium* in New Zealand, one of which is probably native (‘pink bindweed’). To complicate things Ogden (1978) found evidence of hybridisation between *C. sepium* and *C. silvatica*, and suggested that hybridisation may also occur between the native *Calystegia* species and between them and *C. silvatica*. Hybridisation of *C. silvatica* and *C. sepium* has also been reported in Europe and some authors there regard them as subspecies (Williams 2009).

New Zealand has two endemic and two introduced species of *Convolvulus* (Webb et al. 1988). The native species, *C. fractosaxosa* and *C. verecundus*, have restricted distributions (Webb et al. 1988). One of the introduced species, field bindweed (*C. arvensis*), is a significant agricultural weed in many countries and is considered to be the 12th most important weed in the world (Holm et al. 1977). The other, *C. sabatius*, is an ornamental plant which only occasionally escapes from the garden (Webb et al. 1988).

Biological control of other bindweeds

Research into natural enemies

Convolvulus arvensis is notoriously difficult to control by mechanical and chemical methods and the potential of biocontrol has been of interest to researchers since the late 1960s. The fauna associated with *C. arvensis* and closely related *Convolvulus* and *Calystegia* species, such as *C. sepium*, has been fairly well documented with studies in Canada (Mohyuddin 1969), Mediterranean Europe (Rosenthal 1980; Rosenthal & Buckingham 1982), Pakistan (Baloch 1974, 1977), and more recently Slovakia (Tóth et al. 1998; Tóth 2000).

The surveys show that there are at least 150 herbivorous insects and mites that attack *Convolvulus arvensis*, and closely related *Convolvulus* and *Calystegia* species, both in the plants native and introduced ranges (Mohyuddin 1969; Baloch 1974; Rosenthal 1980; Rosenthal & Buckingham 1982; Tóth 2000). However, none of the species found attacking *C. arvensis* are strictly monophagous (feed on a single host). Many also damaged *Ipomoea* species (sweet potato, morning glories) and those with the narrowest host-range fed on both *Convolvulus* and *Calystegia* species (Baloch 1977; Parrella & Kok 1978; Rosenthal 1980; Rosenthal & Buckingham 1982).

Potential biocontrol agents

In 1970 the first biocontrol programme for a bindweed was initiated when the University of California and the United States Department of Agriculture (USDA) began their search for biocontrol agents for *Convolvulus arvensis* (Rosenthal 1980). After much research and testing permission was given to release two insects, a moth (*Tyta luctuosa* (Denis & Schiffermüller)) and a mite (*Aceria* (*Eriophyes*) *malherbae* (Nalepa)) (Rosenthal et al. 1988; Rosenthal & Platts 1990).

Tyta luctuosa

Tyta luctuosa is a leaf-eating noctuid moth. Adult moths lay eggs on *Convolvulus arvensis* stems and flower buds and the larvae feed at night on leaves and flowers (Rosenthal et al. 1988). In laboratory tests larvae fed on and completed development on *Convolvulus* and *Calystegia* species, including *Calystegia sepium* and several native North American species (Rosenthal 1978; Clement et al. 1983). Further testing showed that the larvae had no obvious preference between *Convolvulus arvensis* and *Calystegia sepium* (Chessman et al. 1997).

Despite concerns raised about non-target attack on native species permission was given to release *Tyta luctuosa* in the United States in 1986 (Clement et al. 1983; Rosenthal et al. 1988). A population was sourced from Italy and the first releases were made in 1987 in Arizona, Iowa, Missouri, Oklahoma and Texas. Later releases were also made in Canada (Julien & Griffiths 1998; Littlefield 2004).

There has been little success establishing *Tyta luctuosa* in the field. To date the moth appears to have only established in western Colorado and does not seem to be having much impact (J. Littlefield pers. comm.). The biocontrol programme has been further hampered by difficulties in mass rearing the moth because of high larval mortality, possibly due to nutritional problems (Littlefield 2004; J. Littlefield pers. comm.). A study on the impact of *Tyta luctuosa* on *Calystegia sepium* in cornfields showed that it did not make a significant difference to the damage already caused by existing native herbivores (Tipping & Campobasso 1997). A factor that may affect the impact the moth has on *Convolvulus arvensis* is that the majority of the population goes into diapause in late summer (Miller et al. 2000). With few larvae still feeding at this time, the weed would be released from herbivory. However, this could provide an opportunity to apply foliar herbicides as the moth would be diapausing in cocoons in the soil (Miller et al. 2000).

Aceria malherbae

Aceria malherbae is a mite that galls the leaves, stem tips and petioles of *Convolvulus arvensis* (Rosenthal & Buckingham 1982). The gall mite is tiny and worm-like in shape. Both adults and nymphs feed on actively growing leaves and stem buds thus creating galls. Leaves become folded and twisted and the lower surface becomes roughened with small papillae (Littlefield 2004). Host-specificity testing in the laboratory showed that *A. malherbae* fed and reproduced only on *Convolvulus* and *Calystegia* species. This included nine native North American *Calystegia* species, some of which are considered rare or endangered, and *C. sepium* (Rosenthal & Platts 1990). Further investigation of the risks of non-target attack has been inconclusive. However, so far there have been no reports of native plants being attacked by the mite under natural field conditions (J. Littlefield pers.comm.).

Permission to release *A. malherbae* in the United States was given in 1987 (Rosenthal & Platts 1990). A population of the mite was imported from Greece and the first releases were made in Texas in 1989 (Boldt & Sobhian 1993). There has been interest in *A. malherbae* from other countries and, after additional testing, it was released in Canada in 1993, South Africa in 1994 and recommended for release in Mexico in 2004 (Craemer 1995; McClay et al. 1999; Rodríguez -Navarro et al. 2004; Rodríguez-Navarro et al. 2008).

Aceria malherbae has established in four states and been recovered from three more (Littlefield 2004). It has also established in Alberta, Canada (McClay et al. 1999). It is unknown whether the mite established in South Africa as the release site was accidentally destroyed.

Aceria malherbae establishment and the damage it causes to *Convolvulus arvensis* have been variable in North America (McClay et al. 1999). Damage in particular is quite patchy with some plants exhibiting a few slightly galled leaves and others severely stunted to 1–2 cm long, despite growing in fairly close proximity (McClay et al. 1999, J. Littlefield pers. comm.). Monitoring of a release site in Texas showed *A. malherbae* moving 9.6 m in 3 years, to cover a total area of about 250 m², and a peak of 9.5 infested *C. arvensis* crowns per square metre (Boldt & Sobhian 1993). However, no plant mortality has been observed at any release sites. The mite may be more effective in warmer drier climates. A site that has been monitored for 10 years in Montana has not shown a significant reduction in plant/stem density over that time, whereas reports from southern Colorado and Texas indicate the mite may be causing a decrease in *C. arvensis* populations there (J. Littlefield pers. comm.). *A. malherbae* has been released on *Calystegia sepium* but it appears to be a poor host and less damage is caused to it than caused to *Convolvulus arvensis* (Littlefield 2004; J. Littlefield pers. comm.).

Fungal pathogens

Three fungal species have been pursued as potential biocontrol agents for *Convolvulus arvensis* in the form of mycoherbicides (Ormeno-Nuñez et al. 1988; Heiny 1990; Pfirter & Défago 1998). All three cause lesions on the plants leaves (Morin et al. 1990; Heiny 1994; Guntli et al. 1998). *Phomopsis convolvulus* (Ormeno) and *Phoma proboscis* (Heiny) are effective at reducing leaf biomass and cause high seedling mortality (Morin et al. 1990; Heiny 1994). A US patent was taken out for a mycoherbicide using *P. convolvulus* in 1993 (Watson et al. 1993). *Stagonospora convolvuli* (Dearness & House) strain LA39 damages both *Convolvulus arvensis* and *Calystegia sepium*, although symptoms are less severe in the latter (Guntli et al. 1998; Pfirter & Défago 1998). Tests with potted *C. sepium* plants did not show a change in total plant biomass but a reduction in leaf number and rhizome carbohydrate reserves suggests a significant effect long term by draining the plants' food reserves (Guntli et al. 1998).

4.3 Risks

Herbicide options

- Most herbicide options have some risks associated with them and which need to be managed.
- Glyphosate is a non-residual but non-selective and systemic herbicide. It is likely to damage most of the desired vegetation (including most native plant species) if it comes into direct contact with them, especially at rates required to cause significant injury to *Calystegia sepium.* However, it has been successfully used in arable and horticultural situations through use of shielded sprayers, specialised nozzles, low spray volumes and pressures, etc. It would be possible to develop guidelines for its use that will minimise damage to non-target species.
- Hormone herbicides are very damaging to most broadleaved species, even at very low concentrations, through drift, volatility and direct contact. These risks can be minimised through application timings and application technology.
- All herbicide options are also known to have environmental risks, particularly to soil, surface water and groundwater and to various components of the natural ecosystem, as well as humans. There are recommended strategies to manage most of the risks.

Non-herbicide options

- Regular cultivation has many risks associated with soil loss and erosion, loss of soil texture etc. Moreover, cultivation is not a suitable option for riparian margins in most situations.
- The risk of using ground covers is that they might at best only be able to suppress greater bindweed for a short period of time. On the positive side these ground covers are easy to manage with low rates of herbicide should it prove necessary to do so.

Risks of biological control to native species

- The only native plants at risk of attack by the arthropod biocontrol agents released for the control of bindweeds overseas are *Convolvulus* and *Calystegia* species. Host-testing showed that neither *Tyta luctuosa* nor *Aceria malherbae* are specific enough to not attack other *Convolvulus* and *Calystegia* species (Rosenthal 1978; Clement et al. 1983; Rosenthal & Platts 1990). In New Zealand all native *Calystegia* and *Convolvulus* species could be expected to be attacked to some degree. Kumara (*Ipomoea batatas*), which is in the same family and is of high cultural as well as economic importance in New Zealand, would not be attacked.
- None of the fungal species used as mycoherbicides are known to be present in New Zealand, so trials to determine their host range and risks to non-target species would need to be undertaken. From data currently available it is clear that *Stagonospora* sp. isolate LA39 would probably damage the native form of *Calystegia sepium* (Pfirter & Défago 1998).

5 Recommendations

Based on the research already conducted in New Zealand and other countries on *Calystegia* spp. and similar problem perennial weeds, below are some suggestions for research into controlling/managing this weed in riparian margins.

5.1 Chemical control

- Glyphosate is a potential herbicide tool available for use in riparian margins. However, due to the risks involved with this chemical, specific research is required regarding appropriate rates, timing, methods of application, adjuvants, and formulation. Detailed investigations should be undertaken on mitigating damage risks to riparian species and associated native plants.
- The hormone herbicides (including MCPB, MCPA, 2,4-D, dicamba, triclopyr and the new herbicide aminopyralid) are potential options as most of the riparian margins are associated with common pasture species (grasses and legumes). AgResearch has considerable information on use of these materials in pasture. Research questions would relate to how these chemicals could be fitted into the riparian margins and in particular the safety of aminopyralid on native species.
- Fluroxypyr appeared useful on some other invasive vines that lacked hard, woody stems. It could be worth evaluating on young *C. silvatica* especially as damage to non-target species could be less compared with other herbicide options.
- Amitrole may have a place in limited situations and could be worth investigating where riparian species used may have some tolerance to this herbicide.
- Metsulfuron-methyl is likely to also be effective on *C. silvatica* but would also severely damage non-target woody species and therefore not be recommended.
- Investigations on minimising/mitigating potential risks to non-target species should be undertaken.

5.2 Integrated management

- From the literature and AgResearch's research on managing weeds in orchards, there appears to be an opportunity to exploit the suppressive effect of suitable ground cover species. Dense-growing native species, such as rice grass (*Microlaena stipoides*) and toetoe (*Cortaderia* spp.), would be best but vigorously growing herbs such as *Lotus pedunculatus* and creeping buttercup (*Ranunculus repens*) may be able to provide some suppression in the short term. It could also be worth investigating ways of enhancing the suppressing ability of Yorkshire fog (*Holcus lanatus*) as it is densely-growing and very common in riparian situations. The competitive ability of the ground cover species can be supplemented with low rates of MCPB, glyphosate or paraquat.

5.3 Biological control

- *Calystegia silvatica*, greater bindweed, is likely to be a difficult candidate for biocontrol in New Zealand. The natural enemies of this species have not been specifically studied. Such surveys are likely to cost $100,000–$200,000 and may not reveal any suitable potential biocontrol agents. The natural enemies of close relatives, that have been well studied, tend to be oligophagous (feed on several hosts) (Baloch 1977; Parrella & Kok 1978; Rosenthal 1980; Rosenthal & Buckingham 1982). A biocontrol agent for *C. silvatica* in New Zealand would need to be highly specific as attack on native *Calystegia* and *Convolvulus* species would be unacceptable.
- Mycoherbicides could potentially be used to control *C. silvatica* in New Zealand but may not be practical for several reasons. None of the three fungi that have been developed as mycoherbicides overseas occur in New Zealand (Landcare Research New Zealand Fungi Database: NZFUNGI – New Zealand Fungi (and Bacteria), http://nzfungi.landcareresearch.co.nz/html/mycology.asp, accessed 6 November 2009). As they would be new organisms under the Hazardous Substances and New Organisms (HSNO) Act 1996 permission would need to be gained from the Environmental Risk Management Authority (ERMA). Trials would need to be undertaken before such an application was made to assess the suitability of introducing these fungi into New Zealand. The cost of this research and obtaining ERMA approval, if they were in fact suitable, is likely to be $300,000–$500,000. A source of the fungal species would need to be identified, and if it is not available in mycoherbicide form there is the added work and cost to produce it. Overall this would not be a cheap option.

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Appendix 1 *Calystegia silvatica* – synonyms

These were listed as synonyms in various websites. In some cases they are different species rather than synonyms, but all were investigated.

Scientific name
Calystegia barbara
Calystegia inflata
Calystegia physoides
Calystegia silvatica/silvaticum/sylvatica/sylvaticus
Calystegia sepium ssp. *silvatica/silvaticus*
Calystegia sepium var. *sylvestris*
Calystegia sylvestris
Convolvulus
Convolvulus inflatus
Convolvulus sepium var. *sylvestris*
Convolvulus silvaticus
Convolvulus sylvestris
Volvulus sylvestris

Common name
Field bindweed
Giant bindweed
Great bindweed
Greater bindweed
Large bindweed
Shortstalk bindweed
Shortstalk false bindweed
Morning glory
Liseron des bois (French)
Liseron des forets (French)
Gestreepte winde (Dutch)
Waldzaunwinde (German)
Vilucchio maggiore (Italian)

Appendix 2 Useful references to control of *Calystegia silvatica*

1. Rahman A, Sanders P 1992. Herbicides for control of two bindweed species (*Calystegia silvatica* and *Convolvulus arvensis*) in asparagus. Proceedings of the forty-fifth New Zealand Plant Protection Conference: 27–30.

Several herbicides were evaluated for their harvest-time control of *C. silvatica* in 10-year-old asparagus cv. New Zealand Beacon at Horotiu in 1989–90 and of *C. arvensis* in cv. Mary Washington at Horahora in 1990. Most treatments provided good control of sprayed top growth, but considerable emergence of new weed vines from the extensive root systems continued. Imazapyr at rates of 0.5–1 kg/ha gave the best control of both species, with effects lasting through to the following growing season. Triclopyr (1.2 kg/ha), dicamba (0.4 kg/ha), glyphosate (2.16 kg/ha), chlorsulfuron (0.015 kg/ha) and amitrole (4 kg/ha) generally gave good weed knockdown, but regrowth soon occurred. Clopyralid, tested only on *C. silvatica*, did not provide effective control.

2. Report of the Agricultural and Horticultural Research Station, Bristol. 1958.

P. 27. Sensitivity of *Coleus* plants to 2,4,5-T was found to be favoured by low light intensity and short days, approximately four times as much 2,4,5-T being required to produce the same response on *Coleus* plants grown under long-day/high-light conditions as on short-day/low-light plants. Regeneration of *Convolvulus arvensis* from heavily infested plots sprayed in 1957 with 2,4,5-TB 500–1500 ppm was negligible. Simazine at 5 pounds per acre[1] failed to control couch grass [*Agropyron repens*] but dalapon at 5 pounds per acre and particularly at 10 pounds per acre effectively checked it without injuring cordon apple trees. **P. 43.** Willows. On plots that received inter-row ground sprays of 2,4-D 3700 ppm and 2,4,5-TB 3900 ppm in 1957, the ground cover in 1958 consisted entirely of greater bindweed [*Calystegia sylvestris*]. 2,4-D gave better control than 2,4,5-TB, the relative surface coverage on 4 June being 15% for 2,4-D and 30% for 2,4,5-TB against 50% for the control, and on 17 July 60%, 100% and 100% respectively. On plots that had received foliar sprays of 2,4,5-TB, bindweed was completely controlled by 1000 and 1500 ppm but not by 500 ppm. No willow stools were killed by these treatments but the vigour of 1958 growth was reduced.

3. MAFF 1957. Bindweeds. Advisory Leaflet 450. Ministry of Agriculture, Fisheries and Food, Great Britain. 3 p.

A ‘new’ leaflet that describes bindweeds (*Convolvulus arvensis*, *Calystegia sepium* and *C. sylvestris*). Complete control of *Convolvulus arvensis* by cultivation is difficult, although thorough cultivation of bare and half fallows and regular hoeing of row crops will prevent seeding and in time weaken the plant. 2,4-D is promising for control when applied at (amine) 1.5–2 lb and (ester) 1–1.5 lb/acre to cereal stubble 2–3 weeks after harvest, provided the weed has made some new growth and the land will not be cultivated for 2 weeks after spraying. *Calystegia sepium* can be controlled by cultivation in the same way and in some situations spot treatment with 2,4-D or MCPA may prove useful.

[1] 1 acre = 0.405 hectare and 1 lb = 0.4536 kg.

Appendix 3 Useful references to control of *Calystegia sepium* in orchards, vineyards, forests

4. Trouslard B 1991. Sulfosate. Non-selective systemic herbicides. Phytoma 429: 47–49.
The physiochemical properties, toxicology, soil behaviour, mode of action and spectrum of activity of sulfosate (glyphosate-trimesium) are noted briefly. In widespread trials in vineyards and orchards, sulfosate at 12 L/ha gave excellent control of *Cynodon dactylon*, *Convolvulus arvensis*, *Calystegia sepium* and *Agropyron* [*Elymus*] *repens*. In other trials, this rate also gave at least 90% control of *Lolium multiflorum*, *Senecio vulgaris*, *Erodium cicutarium*, *Agrostis stolonifera*, *Sorghum halepense* and *Aristolochia clematitis*.

5. Frank JR, Simon JA 1981. Glyphosate and paraquat effectiveness in woody nursery stock. Weed Science 29: 455–461.
Two- and three-year-old plants of six woody ornamentals were planted in the field in May 1976 and treated with 1, 2 or 3 annual directed applications of glyphosate at 2.2 and 4.5 kg/ha and paraquat at 0.6 and 1.1 kg/ha. Three applications of glyphosate or paraquat were required to control weeds for the entire growing season. Late-season applications of glyphosate in 1977 controlled weeds in early 1978. Glyphosate at 4.5 kg/ha applied twice a year for 3 years controlled *Taraxacum officinale*, *Plantago lanceolata*, *Rumex obtusifolius* and *R. acetosella*. Three annual applications gave 100% control of *Calystegia sepium*, *Cirsium arvense*, *Polygonum pensylvanicum* and *Amaranthus albus*. Crop size, crop quality and marketability of the six ornamentals were not adversely affected by either herbicide. Two or three applications of glyphosate at 2.2 kg/ha or two treatments at 4.5 kg/ha increased plant size of andorra junipers (*Juniperus horizontalis*). Three treatments of glyphosate at 2.2 kg/ha also increased the size of dwarf Japanese yews (*Taxus cuspidata*) and two treatments at 4.5 kg/ha increased the size of boxleaf Japanese holly (*Ilex crenata*).

6. Scalabrelli G 1979. Two years' results of chemical weed control on apple high density planting. Mededelingen van de Faculteit Landbouwwetenschappen, Rijksuniversiteit Gent 44: 717–724.
In an apple orchard in Tuscany, dominated by perennial weeds such as *Convolvulus arvensis*, *C.* [*Calystegia*] *sepium*, *Paspalum distichum*, *Cynodon dactylon* and *Rumex* spp., glyphosate at rates from 0.72 kg to 4.32 kg/ha or dalapon + 2,4-D at rates from 8.5 + 1.36 kg/ha to 21.25 + 3.4 kg/ha were applied in late May and again in early July. At suitable rates of application, the May treatments controlled most weeds for approximately 7 weeks and the July follow-up treatments maintained control for a further 2 months. No symptoms of toxicity were observed on the apple trees. Results confirm the possibility of using these herbicides to control weeds in a zero-tillage system, the herbicide rates being determined by the type of infestation and time of treatment.

7. Bing A 1977. Glyphosate to control perennial weeds in landscape plantings. Proceedings of the Northeastern Weed Science Society, Baltimore 31: 327.
Artemisia vulgaris, *Rhus radicans* and *Agropyron repens* were easily controlled by spraying with glyphosate at 1–1.5 lb/acre. The larger growing Japanese knotweed (*Polygonum cuspidatum*) is controlled with glyphosate at 2–3 lb/acre but it is difficult to spray without also spraying desirable plants. *Convolvulus arvensis* required repeated applications of 2–3 lb/acre for control and *Convolvulus* [= *Calystegia*] *sepium* was even more difficult to control. As new tubers of *Cyperus esculentus* started growing, repeat applications were necessary.Conifers such as juniper (*Juniperus*) and yew (*Taxus*) are fairly tolerant to glyphosate. A rate of 2–3 lb/acre kills the tips of the branches but the plants soon put on new

growth that covers the damage. Canadian hemlock (*Tsuga canadensis*) scorches easily but also grows new foliage and branches. The ground covers English ivy (*Hedera helix*) and Japanese spurge (*Pachysandra terminalis*) tolerate glyphosate at 0.5–1.5 lb/acre and this treatment may provide a new approach to weed control in ground cover plantings.

8. Kafadaroff G, Brunet Y, et al. 1977. Outcome of 6 years' experimentation with glyphosate in tree fruits. Compte Rendu de la 9e Conférence du COLUMA (Comité français de lutte contre les mauvaises herbes): 645–655.

Control of weeds in tree fruits is substantially similar to that reported for vines. However, *Cynodon dactylon* grows more vigorously in orchards due to fertilisation and irrigation; reinfestation is therefore more rapid than in vineyards. *Convolvulus* [= *Calystegia*] *sepium* is well controlled with glyphosate at 3.6 kg/ha, but regrowth is considerable. As in vineyards *Equisetum arvense*, *Hedera helix* and *Rubia peregrina* are resistant to glyphosate. The best treatment times for various weeds are listed, together with herbicide rates required. For mixed infestations of annual and broad-leaved weeds, glyphosate at 2.88 kg/ha should be applied ± simazine; the rate should be increased to 4.32 kg/ha if *C. dactylon* is present. In 1977, evaluation trials were carried out with glyphosate in young fruit trees; symptoms of toxicity as a result of accidental contact of the tree leaves with glyphosate are listed. Applications to the base of fruit trees, or on rootstock shoots, only cause injury if the trees have wounds due to recent pruning or de-budding. Control of rootstock shoots with a solution of 1%, 2.5% or 5% of the formulated product is very good.

9. Kline WL, Selleck GW 1977. Effect of glyphosate applications on hedge bindweed. Proceedings of the Northeastern Weed Science Society, Baltimore 31: 98.

Glyphosate at 4 lb/acre was applied to hedge bindweed (*Convolvulus* [= *Calystegia*] *sepium*) at different stages of plant growth. Leaf chlorosis was visible 3 days after application and within 21 days 95–97% control was achieved. After 6 weeks, regrowth from underground parts reduced control to 50%, 70–75% and 90–95% with application before, at, and after flowering, respectively. There was no visible difference between glyphosate alone or with additives, either in initial activity or the extent of regrowth. All plots were re-treated twice at various stages of plant growth. The first re-treatment controlled regrowth for a month at defined growth stages: 4, 6, 10 and 20 inches[2] tall and flowering. Subsequent regrowth from these treatments differed little in density. The second re-treatment gave 70–85% control of foliage, but the rhizomes revealed only superficial root necrosis. Jack pine (*Pinus rigida*), which was present in some of the plots, showed only superficial needle scorch with one application of glyphosate.

10. Stalder L, Potter CA, et al. 1977. Recent experiences with integrated measures for the control of field and hedge bindweed (*Convolvulus arvensis*, *C. sepium* [= *Calystegia sepium*]) in vineyards. In: Proceedings of the EWRS Symposium on Different Methods of Weed Control and their Integration, Uppsala. Pp. 221–228.

Convolvulus arvensis and *C. sepium* [= *Calystegia sepium*] have become a problem in vineyards in Switzerland, but promising results have been obtained by exploiting the suppressive effect of small annual weeds such as *Stellaria media*, *Lamium purpureum* and *Veronica persica* to supplement treatments with MCPB, glyphosate or paraquat.

[2] 1 inch = 2.54 centimetres

11. Davison JG 1976. Control of the bindweeds *Convolvulus arvensis* and *Calystegia sepium* in fruit crops. Pesticide Science 7: 429–435.
Convolvulus arvensis is the most important species of bindweed in Britain. Established plants spread by means of lateral roots; establishment from seed and fragments of the underground growth is not important. Growth regulator herbicides such as 2,4-D and MCPA give good control in the year of treatment. With the correct rate and timing there is also good control in the year after treatment. Adding paraquat to 2,4-D reduces the effect in the year after treatment. Repeated annual treatment with high rates of chlorthiamid that prevent shoot growth for the entire season are no more effective against the underground growth than the standard rate of 2,4-D. *Calystegia sepium* spreads rapidly by rhizomes and stolons. It is more susceptible than *C. arvensis* to MCPB. [From summary]

12. Agulhon R, Dumartin P, et al. 1975. Latest results of trials for control of perennial weeds in vineyards. Compte Rendu de la 8e Conférence du COLUMA (Comité français de lutte contre les mauvaises herbes): 858–868.
Trials in 1974 and '75 confirmed the reliable control of *Convolvulus arvensis*, *Calystegia sepium*, *Cynodon dactylon* and other perennial weeds in vineyards obtained with glyphosate at 4.5 kg/ha, although in eastern France control was more variable. Oxadiazon at 2 or 3 kg/ha gave good initial weed control but was not sufficiently persistent; the addition of aminotriazole did not improve control. In Champagne, however, oxadiazon eliminated *Convolvulus arvensis* and *Calystegia sepium* when applied after the flowering of the vines. Terbuthylazine + terbumeton at 6.6 + 3.3 kg/ha in the first year and 2.5 + 1.25 kg/ha in subsequent years generally controlled weeds well, but drought reduced their effectiveness. Best control of *Cynodon dactylon* was obtained with dalapon 5 kg + aminotriazole 5 kg/ha at vine flowering, although the risk to vines was considerable.

13. Barralis G, Boidron R, et al. 1975. Trials for control of perennial weeds in vines of Burgundy and Franche Comte. Compte Rendu de la 8e Conférence du COLUMA (Comité français de lutte contre les mauvaises herbes): 869–878.
Evaluation trials in eastern France in 1974 and '75 confirmed the value of glyphosate at 12.5 kg product/ha post-emergence of the weed in controlling *Convolvulus arvensis* in vineyards. *C.* [= *Calystegia*] *sepium*, *Cirsium arvense* and *Ranunculus repens* proved resistant although *C. sepium* might be controlled by either delaying or repeating the treatment. Control of *Rubus* spp. was partial only. Terbuthylazine + terbumeton, although slow-acting, controlled annual weeds well, but *C. arvensis* was not wholly controlled by product at a rate of 20 kg/ha in the first and 10 kg/ha in the second year. Again *R. repens* was resistant. Cyanatryn was applied as a split treatment, 2 kg/ha on 10- to 15-cm shoots of *C. arvensis* and 3 kg/ha when regrowth had reached the same stage; control was only moderate. Annual weeds were well controlled with terbuthylazine 4 kg + aminotriazole 4 kg/ha pre- or post-emergence and with diuron 0.8 + linuron 0.625 + terbacil 0.165 kg/ha pre- or early post-emergence of weeds, although there was some late regrowth with the latter mixture. Yield trials showed no adverse effect on vines after eight consecutive years of zero tillage.

14. Kafdarof G, Rognon J 1975. The use of glyphosate to control weeds in orchards, Compte Rendu de la 8e Conférence du COLUMA (Comité français de lutte contre les mauvaises herbes): 189–198.
Results are given of a series of trials begun in 1972 in which, after a winter treatment with simazine at 3 kg/ha or diuron 2.5 kg/ha (in apples and pears) or bromacil 1.6 kg/ha (in peaches), glyphosate was applied in spring and/or summer, or autumn. *Cynodon dactylon* was controlled for at least 13 months by late-spring applications of 3.6 or 4.5 kg/ha; a second

application between 1 and 2 years after the first totally destroyed *C. dactylon* in most cases. *Convolvulus arvensis* in apple and pear orchards was sprayed with glyphosate at 2.7, 3.6, 4.5 and 5.4 kg/ha after fruit-set (mostly in late May or early June) either before flowering (shoot length 10–15 cm) or when in full flower (shoot length 30–60 cm). Even at the lowest rate regrowth was scant and shrivelled and with all other rates no further treatment was required 13 months later. *Convolvulus* [= *Calystegia*] *sepium*, on the other hand, required treatment with 3.6 or 4.5 kg/ha in two successive years; the most successful treatments were made just before *C. sepium* climbed into the trees. Other perennial weeds controlled included *Agropyron repens* (at 1.8–2.7 kg/ha) and *Phragmites communis* (autumn treatments most effective), while *Malva rotundifolia* and *Potentilla reptans* required repeated applications of 3.6 kg/ha. *Equisetum arvense* and *Rubus* sp. were generally resistant, although *Rubus* sp. showed more sensitivity to autumn treatments. In further trials glyphosate at 0.72–1.8 kg/ha gave good control of late-winter weeds. Selectivity tests showed that there was no root uptake of glyphosate by fruit trees even after repeated applications during 4 years. Trees deliberately sprayed with glyphosate showed symptoms of toxicity only close to the contact points. Spraying the base of the trunk with up to 9 kg/ha caused no injury to young apple trees.

15. Kafdarof G, Rognon J 1975. Uses of glyphosate for weed control in vineyards, Compte Rendu de la 8e Conférence du COLUMA (Comité français de lutte contre les mauvaises herbes): 831–840.
Good control of *Cynodon dactylon* was obtained in French vineyards with glyphosate at 3.6 or 4.5 kg/ha applied in the second half of June. Thirteen months later regrowth was negligible, and 2 years after application regrowth was found only where infestation had been very heavy or well-established. The weed was almost totally eliminated by a repeat application in the second year. Control of *Convolvulus arvensis* was best when applications were made to vigorous plants during flowering; treatments should not be made too early. In the following year a repeat application usually eliminated the weed. A rate of 4.5 kg/ha was required to control *C.* [= *Calystegia*] *sepium*. Many other perennial weeds were controlled at rates from 1.8 to 4.5 kg/ha, while mixed late-winter infestations were controlled at rates from 0.72 to 1.8 kg/ha.

16. Selleck GW, Zabadal T, et al. 1975. Glyphosate for weed control in vineyards. Proceedings of the Northeastern Weed Science Society, New York City: 237–238.
Treatments were applied as directed sprays to *Convolvulus arvensis* and *C.* [= *Calystegia*] *sepium* in New York grapevines at 22 locations in 1973–74; diuron had been applied annually for several years. Treatments were most effective at the budding and flowering stage of bindweed. Economic control was provided by glyphosate at 2 lb/acre but control was reduced by 10–15% by bindweed growth over the 12 months after treatment; complete control was obtained in October 1974 from 2 lb/acre applied in June 1973 and 1974. *Campsis radicans*, *Asclepias* spp. and *Helianthus tuberosus* showed similar tolerance to bindweeds, whereas glyphosate at 1 lb/acre gave 95% control of *Tussilago farfara* and *Cicuta maculata*.

17. Wurgler W, Neury G 1975. Transport of glyphosate in vines, raspberry plants and bindweed, with some morphological effects. Compte Tendu de la 8e Conférence du COLUMA (Comité français de lutte contre les mauvaises herbes): 841–851. See also Weed Abstracts 25: 855.
In experiments in Switzerland on vines, raspberries and bindweed (*Convolvulus arvensis* and *Calystegia sepium*), glyphosate was transported within the plant towards the extremities, causing changes in leaf shape and stunting of plant organs. Small quantities applied to the upper side of a leaf were not apparently transported towards the stem. In general leaf injury in

vines appeared first at the tips of affected branches and moved inwards towards the base. Some transport also seemed to occur through the old wood supporting the affected branches and into other branches. Glyphosate was applied to inter-row turions in raspberries to prevent new cane development. However, some transport took place through the stems to young untreated turions, which then bore misshapen leaves and lost their apical dominance. Fruit-bearing canes appeared unaffected.

18. Baird DD, Shaulis NJ, et al. 1974. Glyphosate for herbaceous perennial weed control in northeastern apple orchards and vineyards. Proceedings of the Northeastern Weed Science Society, Philadelphia 28: 205–212. See also Weed Abstracts 21: 1062.
Glyphosate at 2.2 kg/ha, applied on 10 May and repeated on 27 June, or glyphosate 2.2 kg + terbacil (or simazine) 2.2 kg/ha, applied in May, gave adequate control of the common herbaceous perennials of established New York apple orchards such as *Agropyron repens*, orchard grass [*Dactylis glomerata*], common milkweed [*Asclepias syriaca*] and dandelion [*Taraxacum officinale*]. Grapevines were not injured by glyphosate sprays applied to the vine trunk or to the soil but contact of foliage was injurious; glyphosate has provided excellent control of herbaceous perennial weeds in vineyards throughout the NE. Small single-application plots showed that field bindweed [*Convolvulus arvensis*] could be controlled with 3.3–4.4 kg, hedge bindweed [*Convolvulus* [= *Calystegia*] *sepium*] with 2.2 kg, Virginia creeper [*Parthenocissus quinquefolia*] with 4.4 kg and *Agropyron repens* with 1.1–2.2 kg a.e./ha. In Ontario, glyphosate at 1.1–4.4 kg ± simazine 2.2 kg, terbacil 1.1 kg or metribuzin 1.1 kg/ha, applied during 1972 and 1973 in young non-bearing apple trees, did not injure or inhibit the growth of cv. Idared, cv. Spartan or cv. Red Delicious; annual weeds, *Agropyron repens* and *Veronica* spp. were controlled. Glyphosate caused no injury to any grape cv. in Ontario. A rate of 2.2 kg/ha 5 days after bloom was necessary for the control of *Convolvulus arvensis* but there was some regrowth on plots which received only one treatment. The 1973 treatments of glyphosate did not have any adverse effect on the quality or quantity of the 1973 crops of grapes or apples.

19. Stalder L, Potter CA, et al. 1974. New aspects of weed control in viticulture: elimination or management of weeds? Schweizerische Zeitschrift fur Obst- und Weinbau 110: 246–261.
An integrated method of controlling bindweed (*Convolvulus arvensis* and *C. sepium*) in vineyards is described. These weeds are difficult to eliminate solely by herbicides; they can be kept in check by competition with other plants, combined with the application of low rates of MCPB. Suitable ground-covering competitors include grasses, herbs or, most successful, selected harmless weeds such as *Stellaria media* and *Poa annua*.

20. Agulhon R, Dumartin P, et al. 1973. Control of perennial weeds in vineyards in different regions. Compte Rendu de la 7e Conférence du COLUMA (Comité français de lutte contre les mauvaises herbes): 801–813. See also Weed Abstracts 21: 1876.
Trials in Alsace, Languedoc, Provence and the Bordeaux and Macon regions in 1972 and '73 showed progress in the control of perennial weeds in vineyards. Bindweed (*Convolvulus arvensis* and *C.* [= *Calystegia*] *sepium*) can usually be controlled by terbuthylazine + terbumeton after several years of treatment at rates varying from 2.31 + 1.19 kg to 6.6 + 3.4 kg/ha according to soil and climatic conditions. This mixture gave variable results but it also controlled much of the annual weed infestation. Oxadiazon at 2 or 2.5 kg/ha caused rapid withering of the aerial parts but regrowth was generally vigorous; treatment on weed growth 30 cm high proved most effective around Bordeaux; contact of spray on vine leaves caused

some damage. 2,4-D amine at 1 kg/ha proved the cheapest means of controlling bindweed but care is needed to avoid crop damage; treatment should be made from flowering up to the time when the grapes are beginning to ripen. Monolinuron 1.125 kg + linuron 1.125 kg + mecoprop 0.945 kg + 2,4,5-T 0.36 kg/ha controlled bindweed well in Languedoc and Macon. Glyphosate at 4.5 kg/ha gave good results in all regions; treatments should be made at the latest just before flowering of the weed; no damage was caused to vines provided spray did not touch the leaves. Glyphosate also gave the best kill of *Cynodon dactylon*; dalapon at 5 kg + aminotriazole at 4.8 kg/ha controlled *C. dactylon* but is not recommended because of the high risk to vines. Glyphosate also controlled *Agropyron repens*, *Artemisia vulgaris* and *Sorghum halepense*.

21. Fort G 1973. Vineyard management under minimum cultivation and control of bindweed, Compte Rendu de la 7e Conférence du COLUMA (Comité français de lutte contre les mauvaises herbes): 826–830. See also Weed Abstracts 21: 1878.

Continuation of tests in Savoy has shown that minimum cultivation in vineyards requires two separate herbicide treatments at precise dates. The first treatment with 1.5 kg/ha of simazine must be made in late February or early March to control annual weeds. The second should be made in late June. A number of herbicides give good control of bindweed [*Convolvulus arvensis* and *Calystegia sepium*]; it may be best to vary the product from year to year. Aminotriazole at 4.8 kg/ha controls many broadleaved weeds, leaving stunted bindweed which, on a sloping site, counteracts erosion; 2,4-D amine at 0.8 kg/ha, though not approved for vineyards, gives good control if applied as weed flowering ends, but dandelions [*Taraxacum officinale*] are a problem; oxadiazon at 2 kg/ha destroys all bindweed, but does not control thistles and *Potentilla* spp.; terbuthylazine at 5 kg + terbumeton at 2.5 kg/ha starts slowly and results may be inconsistent, but after 1 year's use weed control is so good that the late winter treatment may be omitted.

22. Kafadarof G, Poisson JC 1973. Glyphosate, a new herbicide for the control of perennial weeds, Compte Rendu de la 7e Conférence du COLUMA (Comité français de lutte contre les mauvaises herbes): 3–13. See also Weed Abstracts 21: 850, 855, 1061, 1062.

The properties, toxicology, and mode of action of glyphosate are briefly discussed. An account is given of tests carried out in France during two years on the effectiveness of glyphosate-isopropylamine. In vineyards rates of 4.8–6 kg/ha were effective against *Cynodon dactylo*n 20–40 cm high; 3 months after application glyphosate had destroyed 90–94% of the weed compared with a 31% kill given by aminotriazole + ammonium thiocyanate 5 kg/ha and 68% kill with aminotriazole + ammonium thiocyanate 5 kg + dalapon 5 kg/ha. *Convolvulus* sp. was controlled best by application immediately before flowering. There was some phytotoxicity where the spray contacted the vine shoots or leaves and it is recommended that sprayers equipped with fan or deflector-nozzles be used to avoid drift. In maize stubble glyphosate at 2.8 kg/ha controlled *Agropyron repens* (92–96% kill) more effectively than did aminotriazole + ammonium thiocyanate at 5 kg/ha (77–87% kill). *Sorghum halepense* also showed greater susceptibility to glyphosate 2.4 kg/ha than to aminotriazole + dalapon. Glyphosate, applied either before or after turning the stubble, did not affect crop yields at rates up to 11.52 kg/ha except when applied to a prepared seedbed one week before sowing barley. With 11.52 kg/ha there was yellowing and thinning of the crop and a markedly reduced yield. It is recommended that glyphosate at 2–3 kg/ha (for *A. repens*) and 3.6–4.8 kg/ha (for *C. dactylon*) be applied to the regrowth after burning or crushing the stubble. Soil should then be left undisturbed for 3 weeks. Tables are given of the results of selectivity tests in vineyards, orchards and cereals.

23. Stalder L, Potter CA, et al. 1973. New herbological aspects in viticulture: weed control or management? Schweizerische Zeitschrift fur Obst-und Weinbau 109: 246–261.

Experiments in eastern Switzerland in vines trained up wires showed that dense infestations of *Convolvulus arvensis* and *C.* [= *Calystegia*] *sepium* could be suppressed by a ground cover composed of grasses and legumes and of weeds unlikely to become a problem (such as *Stellaria media* and *Poa annua*) and could be eliminated by the additional use of small amounts of MCPB salt.

24. Fort G 1971. Weed control in vineyards in Savoy, Compte Rendu 6e Conférence du COLUMA (Comité français de lutte contre les mauvaises herbes): 686–693. See also Weed Abstracts 21: 1878.

Six years' trials have shown non-cultivation to be beneficial to grapevines. Chlorthiamid at 10.0 kg/ha controlled a range of broad-leaved weeds, but *Ranunculus* spp. were resistant and some regrowth was noted in *Convolvulus arvensis*. Simazine at 1.5, 3.0 or 5.0 kg + aminotriazole at 4.8 kg/ha afforded good weed control, except for *Convolvulus arvensis* and *Convolvulus* [= *Calystegia*] *sepium*, but after 4 years' application the crop showed symptoms of toxicity. A system in which simazine, used for the control of annual weeds, was followed 2 months later with aminotriazole for the control of *C. convolvulus* and *C. sepium*, proved effective; the rate of simazine could be reduced progressively. Atrazine at 3 + aminotriazole at 4.6 kg/ha gave better control of *C. convolvulus* and *C. sepium* than did simazine + aminotriazole. Atrazine alone was not well tolerated by the crop. RP 17 623 [4-(2,4-dichloro-5-isopropoxyphenyl)-2-t-butyl-1,3,4-oxadiazolin-5-one] at 3.8 + simazine at 1.5 kg/ha applied in March gave good control of broadleaved weeds including *C. arvensis* and *C. sepium*. 2,4-D amine at 0.8 kg/ha applied after flowering gave almost complete control of these two species but the risk of crop damage from this compound is high.

25. Davison JG 1970. Experiments with dichlobenil, chlorthiamid and MCPB for the control of *Convolvulus arvensis* and *Calystegia sepium* in gooseberries. Proceedings of the 10th British Weed Control Conference: 788–795.

Dichlobenil and chlorthiamid were applied at 10 and 20 lb/acre in March/April and May in two successive years. In general, chlorthiamid was more effective than dichlobenil, and the rate was more important than the time of application. Marginal chlorosis of crop leaves occurred in both years at all three sites used. Dichlobenil at 20 lb/acre applied as the fruits were swelling caused a significant increase in fruit-drop at one site but yields were not affected. Dichlobenil and chlorthiamid gave better control of *C. arvensis* in the year of treatment than did MCPB at 2.5 lb/acre applied the previous August or September. MCPB in late August was more effective in controlling *C. sepium* than was dichlobenil or chlorthiamid at 10 lb/acre applied in the following spring. Control of both weeds with dichlobenil and chlorthiamid was generally better when MCPB was applied in the previous season.

26. Porter LA 1968. Weed control in cane and bush fruits. Proceedings of the 21st New Zealand Weed and Pest Control Conference: 67–71.

Paraquat and diquat (2 lb ai/gal[3]) in aqueous dilutions of 1: 700 or 1: 300 (directed) may be applied in the dormant season of established raspberry, bramble, blackcurrant and gooseberry plantations to provide a weed-free soil for the application of simazine at 2–3 pounds per acre at the start of the growing season. Black polythene sheet 0.005 in. thick costing $280/acre and

[3] 1 gallon = 4.546 litres

lasting 6 years may be laid in 3-ft-wide[4] strips and the crop planted through it. Sheep may be grazed in all the crops, and geese until late dormancy in raspberries or gooseberries or until a month before harvest in blackcurrants. Methyl bromide can be used to sterilise soil 1 month before planting blackcurrants. White clover is suggested for a non-aggressive sward cover between crop rows. *Agropyron repens* can be controlled before planting by methyl bromide or aminotriazole+ammonium thiocyanate combined with cultivations; paraquat can be used to retard growth in established crops. 2,4-D amine or 2,4-D polyethylene glycol ester at 2 pounds per acre, applied at early dormancy of the crop, will give a degree of control of *Rumex* spp., asulam at 1.5 pounds per acre shows promise and repeated applications of diquat during the dormant season check regrowth in spring. *Trifolium repens* can be eradicated by directed applications of 2,4,5-T at 3.6 pounds per acre. 2,4-D amine at 1 lb in 150 gallons of water, applied to run-off, can be used against *Calystegia sepium*. There appears to be no treatment capable of eradicating an infestation of *Oxalis lati-folia* from a crop, but non-cultivation may restrict its spread.

27. MAFF 1965. Bush fruits. Bulletin of the Ministry of Agriculture, Fisheries and Food, Great Britain. 68 p.

Pp. 25–28. *Blackcurrants.* In nursery beds, simazine at 1 pound per acre can be applied during autumn or winter following the planting of cuttings, provided that the soil is allowed to settle before spraying to reduce the risk of the chemical being carried down to the root zone. In mature bushes, simazine at 1–2 pounds per acre applied to clean ground will control most annual weeds for the season. A 5 pounds per acre rate will give some control of chickweed (*Stellaria media*) and creeping bent (*Agrostis stolonifera*), but it is inadvisable to use high rates of simazine for two consecutive years, especially on light sandy soils. Dalapon at 8 pounds per acre can be safely used in autumn to control established perennial grasses, including *Agropyron repens* [*Elymus repens*]. For seedling grasses a 4 pounds per acre rate can be applied any time before bud-burst. MCPB at 2–3 pounds per acre can be applied as a directed spray in the autumn to control *Ranunculus repens* or *Sonchus* spp. and *Carduus* spp. When applied in late August or early September, MCPB at 2–3 pounds per acre has also given effective control of bindweeds (*Convolvulus arvensis* and *Calystegia sepium*) with only slight damage to the crop. 2,4,5-TB at 2–3 pounds per acre can be safely used throughout the season to control bindweeds, but is less effective than MCPB against other broadleaved weeds. Chlorpropham at 1–2 pounds per acre may be safely used as a directed spray for the control of chickweed. Paraquat and diquat at 1–2 pounds per acre have shown promise for clearing the ground cover either before or with a simazine treatment. **P. 54**. *Gooseberries*. Most of the recommendations for blackcurrants apply also to gooseberries, except that dalapon should be used only in established bushes. Dalapon at 4 pounds per acre can be applied during November or December to control grass seedlings, but the higher rates necessary for the control of established grasses may cause temporary injury to the crop. For short-term control of weeds, 2,4-DES at 2–5 pounds per acre will control germinating weeds for about one month. **P. 65**. *Redcurrants*. No recommendations can be given, as insufficient information is available. Simazine at 2 pounds per acre applied to clean land has kept plantations free from seedling weeds for most of the season. MCPB at 2–3 pounds per acre has been used in late summer after active growth has ceased for the control of bindweeds and it appears that redcurrants are as tolerant as blackcurrants to this treatment.

[4] 1 foot = 0.3048 metre

28. Julliard B 1965. The destruction of perennial weeds, especially bindweeds, in vineyards, Paper read at 3e Conférence du COLUMA (Comité français de lutte contre les mauvaises herbes). 10 p.

Various foliar-applied, translocated herbicides were examined for their activity against five troublesome perennial weeds of vineyards. The treatments were intended to complement the soil-acting compounds, the continued use of which has led to the replacement of annual weeds by a resistant perennial flora. Amitrole-T (amitrole at 5 kg + NH 4 SCN at 10 kg) + 2,4-D at 1.3 kg/ha in July 1962 limited the regrowth of *Aristolochia clematitis* in June 1963 to a few chlorotic shoots. Amitrole-T in June killed 90% of plants of *Cirsium arvense*, but amitrole at 5 kg +atrazine at 5 kg/ha killed only 70%. The susceptibility of this species to 2,4-D amine in 1959–62 was greatest during late August – early September. Amitrole-T (amitrole at 4 kg +NH 4 SCN at 4 kg) + atrazine at 4 kg/ha gave the best (90%) kill of *Agropyron repens* [*Elymus repens*] when treatment was delayed till 1 month after shoot emergence; it was more effective than mixtures in which the atrazine was replaced by simazine, diuron or linuron and much more effective than dalapon at 5 kg/ha or amitrole-T alone. Applying paraquat at the end of September also gave very good control of *A. repens*. Annual applications of amitrole-T + either simazine, atrazine or diuron [see preceding abstract] controlled *Convolvulus arvensis* and *Calystegia sepium*. In the good growing conditions of 1963 applying 2,4-D amine at 2 kg/ha in late August – early September, to coincide with the period of maximum translocation of photosynthate into the rhizomes, gave 95% kill and an increased grape yield valued at 4,500 F/ha. On the above showing, the use of amitrole-T + a soil-acting compound or applying a soil-acting compound in spring, followed by 2,4-D in autumn, would appear to be feasible alternatives to cultivations for creating and maintaining weed-free conditions in vineyards.

29. Julliard B 1965. The use of herbicide mixtures based on amitrole in vineyards. Compte rendu 9e Conférence du COLUMA (Comité français de lutte contre les mauvaises herbes):

Eleven years' trials in vineyards in Alsace have shown that the constant use of soil-acting compounds leads to the gradual replacement of susceptible annual weeds by resistant perennials, but that these can to some extent be controlled by amitrole-T. The trials here reported were designed to study the timing of a dual-purpose treatment intended to control both. A trial in 1963 established that mixtures in which amitrole-T was combined with simazine or diuron were more effective when applied pre- than post-emergence, of thistles [*Cirsium arvense*] and bindweeds [*Convolvulus arvensis* and *Calystegia sepium*]. Amitrole-T+atrazine was better still and in this case application made pre- or early post-emergence, was equally effective. Interim observation of a long-term experiment showed that applications of amitrole-T (amitrole 2.5 kg/ha + NH 4 SCN 2.5 kg) + atrazine 4 kg made annually since 1962 at a time when the first perennial weeds had just emerged (before bud-burst of the cv. Riesling) had by 1965 reduced bindweed populations by nearly 75%. Mixtures containing simazine or diuron were less effective. Monuron at 4 kg/ha in spring, with follow-up application of 2,4-D 1 kg in autumn, was even better than amitrole-T + atrazine, but occasional toxicity to the crop caused it to be replaced in 1965 by linuron.

30. Stott KG 1964. The effect of time of application of some herbicides on the control of weeds in mature willow beds. Report of the Agric. Hort. Research Station, Bristol, 1963. Pp. 186–192.

Where herbicides were applied in 100-gallon[5] spray, good control of *Cirsium* spp. in willow (*Salix triandra*) beds was achieved with amitrole at 2 and 4 pounds per acre and fair control with MH [maleic hydrazide] at 12 pounds per acre, but not at 6 pounds per acre. At the higher rate, both herbicides controlled *Poa annua* in a 3-year-old bed, but were ineffective against a dense sward consisting mainly of *Holcus lanatus* and *Agrostis* spp. in a mature bed. Both chemicals were toxic to willows if applied overall to stools in May. Damage to grazed stools (shoot length 2 in.) was greater than at bud break (shoot length 0.5 in.). The damage caused by MH was permanent, whereas there appeared to be complete recovery from amitrole at 4 pounds per acre applied at bud-break and at 2 pounds per acre applied to grazed stools. No damage occurred from either herbicide applied between the rows in June, and none is considered likely to occur from the treatment of dormant stools in March. 2,4-D at 1.25 pounds per acre in 100-gallon spray caused extensive damage at bud-break to stools with more than two broken buds, but showed promise in controlling *Calystegia sepium* when carefully directed between the rows.

31. Goddrie PD 1961. Bind-weed control in currants. Fruitteelt 51: 989.
MCPA at 1 kg active ingredient per hectare effectively controlled *Calystegia sepium*. *Convolvulus arvensis* was controlled by 40% MCPB at 2 ½ kg/ha. Sprays are best applied between harvesting and the beginning of October.

32. Julliard B 1961. New weed control trials in vineyards. Compte rendu Conférence du COLUMA (Comité français de lutte contre les mauvaises herbes): 8.
The soil and rainfall in the Alsatian vine-growing region is described. The presence of weeds at budding increases the risk of frost and in summer increases the risk of mildew, *Oidium* and *Botrytis* infection. The effect on weeds in trials in Alsace with monuron, simazine, diuron, dalapon, 2, 6-dichlorobenzonitrile (DBN), amitrole and atrazine is briefly described, also the effects on the vine of amitrole, dalapon, DBN and EPTC in pot trials, and of foliage sprays of simazine, monuron and diuron. In a field trial on a clay soil, no adverse effects were observed in the year of application or in the following years after applying monuron 32 kg/ha, simazine 30 kg/ha or amitrole 20 kg/ha although in 1955, monuron 32 kg/ha had killed the vine in a permeable soil. In another trial, monuron at 8 kg/ha applied 3 years running caused a yield reduction of 14.1% in the third year, whereas simazine at 5 kg/ha applied similarly had no adverse effect on yield. In a 4-year trial there was no difference in growth, yield or sugar content of grapes from plots given normal cultivation and those given reduced or no cultivation in combination with herbicide treatment. In the latter case the soil density was increased and the soil moisture status not significantly affected. The limited effect of residual herbicides on perennial weeds led to trials with 2,4-D (sodium or amine), 2,4,5-T, mecoprop, and MCPB applied in August when vine leaves were fully grown and buds dormant. No injury or yield reduction has been caused in 3 years' trials, and after 1 year, 2,4-D 1.2 kg/ha resulted in 50% reduction of *Cirsium arvense*, 50–60% of *Convolvulus arvensis* and *Convolvulus [= Calystegia] sepium* and 100% of *Ranunculus acris*.

33. Mulder A 1960. The control of bindweed in currants. Fruitteelt 50: 1057.
Bindweed (*Convolvulus* [= *Calystegia*] *sepium*) in currants was successfully controlled by sprays of either MCPA (a.i. 1 kg/ha) or MCPB (2.5 or 5.1 of a 40% material per hectare).

[5] 1 gallon = 4.546 litres

Appendix 4 Other general references

34. Rask AM, Andreasen C 2007. Influence of mechanical rhizome cutting, rhizome drying and burial at different developmental stages on the regrowth of *Calystegia sepium*. Weed Research (Oxford) 47: 84–93.

The regrowth of *Calystegia sepium* was studied in three types of experiments during spring 2003 and spring 2004. In one glasshouse experiment, rhizome fragments were planted in pots and either harvested at six different developmental stages to assess their undisturbed development and growth or harvested at 420-day degrees after burial to measure their regenerative capacity. Regrowth gradually declined as the plants had more expanded leaves at the time of burial. Minimum regenerative capacity was found when plants had 4–8 fully expanded leaves and this coincided with the growth stage of minimum dry weight of underground regenerative organs. The effects of burial depth and rhizome fragment length were studied in outdoor container experiments. Burial at 15 or 25 cm reduced above- and below-ground biomass in 2004, while 25-cm-deep burial was necessary to reduce regrowth in 2003. Fragmentation had generally little effect on production of above- and below-ground biomass, whereas burial and fragmentation delayed emergence time. Sensitivity of rhizomes to drying was studied in a growth chamber. Drying periods of 12 or 24 h did not have an influence on the production of aerial shoots, whereas 48 or 96 h reduced production of above-ground biomass significantly. The experiments indicated that the minimum regenerative capacity would be at about 5–6 leaf stage and that mechanical disturbance at this stage would optimise weed control.

35. Dixon FL, Clay DV 1997. Control of *Calystegia sepium* (hedge bindweed) and *Sonchus arvensis* (perennial sow-thistle) in poplar short-rotation coppice. Aspects of Applied Biology 49: 79–84.

Two experiments were carried out at Hunstrete, near Bristol, UK, to test the efficacy and selectivity of potential treatments for the control of *C. sepium* in poplar [*Populus*] cv. Trichobel and of *S. arvensis* in poplar cv. Boelare. With *C. sepium*, oxadiazon applied before weed emergence in March or to young shoots in May gave effective control for 1 year without crop damage. Amitrole, glufosinate, glyphosate and paraquat applied in May gave short-term control but did not suppress growth of the weed later in summer. With *S. arvensis*, the recommended treatment of clopyralid at 0.1 kg/ha a.i. followed by 0.2 kg/ha a.i. after 3 weeks was more effective than single applications, but re-treatment was required in the second year. Single applications of clopyralid at the higher rate were more effective on *S. arvensis* at the flowering-bud stage than at the earlier leaf-rosette stage. Two applications of glufosinate directed to minimise crop contact gave largely complete control in the year of treatment, but glyphosate applied at the leaf-rosette stage was less effective. There was little crop damage from any treatment. Compared with the weedy control, poplar growth was greatly increased by the glufosinate treatment but not generally by clopyralid.

36. Ast A v, JM v Groenendael 1993. The population dynamics of the pseudo-annual *Calystegia sepium* (bindweed): a troublesome weed in the Netherlands. Mededelingen van de Faculteit Landbouwwetenschappen, Universiteit Gent 58(3A): 973–982.

Field trials and greenhouse experiments were conducted to investigate the population dynamics of *Calystegia sepium* (a plant able to propagate by seeds as well as rhizome fragments). Two experiments were conducted: in the first the effect of depth of burial (2, 4, 8, 16 or 32 cm deep) upon the sprouting of rhizome fragments possessing 1, 2 or 3 intact nodes was investigated, and in the second the growth and development of rhizomes with 1 node under varying light conditions was studied. Experiment 1 illustrated the enormous potential for vegetative reproduction possessed by *C. sepium*; in all cases sprouts emerged and rhizomes with more nodes produced more sprouts. It was therefore concluded that the limiting depth for *C. sepium* to produce above-ground sprouts was >32 cm. The results produced by experiment 2 indicated that light reduction has a very negative effect on the DM production of *C. sepium*, with only 10% of the DM production under normal daylight being produced under shaded condition; the same negative effect is found with the production of rhizomes and buds. It was concluded that *C. sepium* is a very light-sensitive species that is able to produce several sprouts over a prolonged period from one node on a rhizome fragment. Soil tillage type has a significant influence upon *C. sepium*, with deep tillage (which buries the fragments deep below the surface) helping to control this weed, especially if it is not greatly fragmented.

37. Himme M v, Stryckers J, et al. 1983. A study of perennial weeds: bindweeds. Mededelingen van het Centrum voor Onkruidonderzoek 38: 186–191.
Experiments with *Convolvulus arvensis* showed that shoot vigour depended more on rhizome length than on depth of burial. The average number of shoots fell only when rhizomes were more than 30 cm deep. In plants grown from rhizomes collected in various parts of eastern and western Flanders, considerable variation was observed in leaf shape, even in those from the same original site. A similar experiment with *Calystegia sepium* revealed much less variation. Flowers of *Convolvulus arvensis* varied in colour according to environmental variations, while those of *Calystegia sepium* were uniformly white. Three to four weeks after application of 2.5 kg 2,4-D triethanol amine, 1.125 kg 2,4-D + 1.125 kg MCPA dimethyl amine + 0.27 kg dicamba DMA/ha or 2.5 kg glyphosate/ha, all *C. sepium* plants were dead; in the next yearr control was still good and 21 months after treatment glyphosate plots had the least regrowth.

38. Kline WL, Selleck GW 1978. Factors affecting hedge bindweed control with glyphosate. proceedings of the Northeastern Weed Science Society 32: 283.
Roundup (glyphosate) applied at 3.36 and 4.48 kg/ha on a moist waterway and a dry abandoned potato field gave satisfactory control of hedge bindweed [*Calystegia sepium*] for 12 months. July applications provided 70–80% control in the moist area. Late summer or autumn applications of Roundup were more reliable. Applications of 4.48 kg/ha in July maintained 85–90% control for one year while a September treatment gave 95% control; an additional treatment was required at the end of 12 months. Treatments were applied in June to tilled and untilled soil. Roundup at 4.48 kg/ha on tilled soil took three treatments to maintain 95% control and one fewer on untilled plots; two additional applications were needed the following year to maintain 99% control. Directed treatments had no effect on a range of woody ornamentals unless accidental wetting occurred. Roundup at 4.48 kg/ha applied in autumn 1976 was followed by a natural succession of *Solidago* sp., *Aster ericoides* and *Ambrosia artemisiifolia* in the following spring, but maintained a 95% control of hedge bindweed throughout 1977. Observations at another location pointed to biological control by the agus tortoise beetle (*Metriona bicolor*).

39. Sandberg CL, Meggitt WF, et al. 1976. Can glyphosate control field bindweed? Proceedings North Central Weed Control Conference 31: 93.
Glyphosate at >1.12 kg/ha gave excellent control (at least 90%) of field bindweed [*Convolvulus arvensis*] when sprayed from June to October, provided the weed was developed to the post-bud stage. Tillage before application reduced control to nil after 12 months, while tillage 2 weeks after application had no effect on control after 12 months but

reduced control from 80% to 50% after 18 months. In most cases re-treatment was necessary after one or two growing seasons to maintain control. The studies were carried out on both muck and mineral soils. Hedge bindweed [*Calystegia sepium*] was very susceptible to glyphosate and excellent control was obtained with 1.12 kg/ha and above with no need for re-treatment a year later.

40. Ivon Watkins 1967–68. Convolvulus or morning glory or bindweed or cornbind and cape ivy and sorrel and periwinkle can now be controlled in garden and field. Service, pp. 10–12.

Brief recommendations are given for the control of *Convolvulus* spp., including *C.* [= *Calystegia*] *sepium*, with Banvine (2, 4-D+Banvel D [dicamba dimethylamine]). Best results are obtained by spraying in the spring to early summer when the weed is in full leaf and actively growing. Suggested rates are 2 oz[6]/gallon water or, for larger areas, 1 quart[7]/44 gallon water. Banvine also controls cornbind [*Polygonum convolvulus* [*Fallopia convolvulus*]], cape ivy [*Senecio mikanioides*], sorrel [*Rumex* sp.], periwinkle [*Vinca major*] and wandering Jew [*Tradescantia albiflora*].

41. MAFF 1963. Perennial bindweeds. Advisory Leaflet 450. Ministry of Agriculture, Fisheries and Food, Great Britain. 4 p.

Notes are given for the identification of field bindweed (*Convolvulus arvensis*) and bellbine (*Calystegia sepium*). Good control of *C. arvensis* on uncropped land is obtained with MCPA, MCPB, 2,4,5-TB and 2,4-D sprayed when the weed is approaching the flowering stage, followed by cultivation to discourage re-establishment. *Convolvulus arvensis* is also controlled with MCPA applied as spot-treatments in asparagus after cutting, with directed sprays of MCPB and 2,4,5-TB under blackcurrants after harvesting, on stubble with 2,4-D, providing no cultivation is carried out for 2–3 weeks after treatment, and with 2,4-D or MCPA 6 months or more after sowing or laying turf. Low rates of MCPA may be used to control *C. arvensis* in potatoes during active growth, but some reduction in yield may result. *Calystegia sepium* is moderately susceptible to both MCPA and 2,4-D.

[6] 1 ounce = 28.35 g
[7] 1 quart = 1.136 litres

Appendix 5 Control of invasive vines (excl *Calystegia* spp.)

Actinidia deliciosa

42. Sullivan JJ, Mather J, et al. 2007. Control of wild kiwifruit (*Actinidia* species) in Bay of Plenty, New Zealand. Acta Horticulturae 753, Vol. 2: 583–590.
A large population of wild kiwifruit, mostly *Actinidia deliciosa*, has grown in the Bay of Plenty region of New Zealand over the past 30 years, fueled by the increasing commercial success of kiwifruit production. This fast-growing non-native woody vine has invaded native forest and scrub and commercial *Pinus radiata* plantations. The environmental impacts of wild *Actinidia* have led it to be listed as a Total Control Pest Plant in the Environment Bay of Plenty Regional Pest Management Strategy. Wild vines can be reliably killed with any of sprayed Tordon® Brushkiller (picloram/triclopyr), Grazon® (triclopyr) and stump treatment with Vigilant™ gel (picloram). Some $NZ523,000 was spent from 1998 to 2005 on controlling wild *Actinidia* in the Bay of Plenty, funded by partnerships between the kiwifruit industry and Environment Bay of Plenty. In the four control seasons of 2001/02 through to 2004/05 more than 21 000 vines have been killed. Similar control efforts each season have found progressively fewer vines (almost 6000 fewer vines in 2004/05 than 2001/02), indicating that the population is being successfully reduced. Between 67% and 96% of the pre-control population of established wild vines are estimated to have been removed. Sustained control over several more years will be required to reduce this population to an easily manageable size. This is complicated by continued recruitment into the wild population from commercial crops, principally via birds feeding on reject kiwifruit fed out to farm stock. We suggest that other countries that commercially propagate wild kiwifruit outside of its native range take care to prevent wild populations from establishing in surrounding vegetation.

Anredera cordifolia

43. Vivian-Smith G, Lawson BE, et al. 2007. The biology of Australian weeds *Anredera cordifolia* (Ten.) Steenis. Plant Protection Quarterly 22(1): 2–10.
This review provides information on the morphology, history, geographical distribution, habitat, relationships with other species, growth and development, reproduction, dispersal, population dynamics, importance, toxicity and management (using herbicides, mechanical and cultural methods as well as biological control agents) of *A. cordifolia*.

44. Webb HJ, Harrington KC 2005. Control strategies for Madeira vine (*Anredera cordifolia*). New Zealand Plant Protection 58: 169–173.
Madeira vine is an environmental weed with both aerial and subterranean tubers, and is listed as a Surveillance Plant Pest by Manawatu-Wanganui Regional Council. A field trial conducted in various locations around Wanganui, New Zealand, showed mature vines and their attached tubers were best controlled using metsulfuron-methyl, although reasonable control was also provided by a triclopyr/picloram mixture and by glyphosate. The control of regrowth from buried tubers was investigated in a glasshouse trial. Herbicides that gave good control of 3-month-old plants included the above herbicides and also tribenuron-methyl, fluroxypyr and amitrole. For eradication purposes, treatments were assessed for destroying aerial tubers collected from isolated plants. Tubers were killed by freezing, by heating to temperatures of 80°C or above for 24 h or by boiling for a few minutes, but any pulverisation

techniques needed to be thorough. Tubers immersed momentarily in high concentrations of picloram, triclopyr or fluroxypyr did not regrow after burial.

45. Prior SL, Armstrong TR 2001. A comparison of the effects of foliar applications of glyphosate and fluroxypyr on Madeira vine, *Anredera cordifolia* (Ten.) van Steenis. Plant Protection Quarterly 16(1): 33–36.

A study was conducted at Beechmont in Queensland, Australia, from March to November 1998 to compare the efficacy of one, two and three foliar applications of various concentrations of glyphosate and fluroxypyr ester on Madeira vine (*Anredera cordifolia*). Repeat applications were made at 3-monthly intervals. Counts of Madeira vine density within experimental quadrats were made following treatment applications in autumn, winter and spring 1998. Fluroxypyr applied at 1 and 2 g/L water and Glyphosate 360 applied at 3.6 and 7.2 g/L were equally effective in controlling all vine stems present at application. Fluroxypyr at 1 and 2 g/L water were the only treatments that significantly reduced the number of new stems of the plant in the months between applications. Quadrats treated with fluroxypyr at its lowest effective concentration (1 g/L) had less Madeira vine and other broadleaved weeds, but contained competitive grass species such as kikuyu [*Pennisetum clandestinum*], which, from a management perspective, may be beneficial by providing competition. Canopy establishment can eventually shade such species out. Removal of competition through the use of the non-selective herbicide glyphosate may favour reinvasion from Madeira vine subterranean tubers, especially if applied at a time of year where translocation activity is not high. Though the pooled population density was significantly lower from April to July 1998, there were no significant changes within the population trajectories in quadrats treated with fluroxypyr at 1 g/L, indicating no preferential time for spraying. Model predictions indicated that monthly applications of fluroxypyr at 1 g/L at this particular site would be required to stabilise the population (in the absence of recruitment of new individuals), and subsequently reduce it at a rate dependent upon the mortality of the subterranean tuber 'bank'. The length of time over which herbicide applications would be required would have to be determined empirically.

Araujia sericifera

46. Gomez de Barreda D, Busto A d, et al. 1992. *Araujia sericofera* Brot. – a new weed in citrus orchards. Proceedings, IXe Colloque international sur la biologie des mauvaises herbes, 16–18 September 1992, Dijon, France. Pp. 95–102.

Following a description of *Araujia sericofera* and a discussion of its spread from its native South America, the results of research conducted by IVIA on various aspects of the weed are reported. Biomass production was shown to be dependent on weed spacing (FW of 57 600 and 24 300 kg/ha being produced 10 months after sowing at 40 × 60 and 40 × 120 cm spacing, respectively) and water availability (FW of 7150 and 19 745 kg resulting from irrigation with 2.7 and 21.6 L water per plant, respectively). Extracts of dibromoethane and germanicol from *A. sericofera* seeds were shown to be toxic to *Oncopeltus fasciatus*. In field and greenhouse trials, good control of *A. sericofera* was achieved with 4 kg/ha each of bromacil, diuron, simazine and 15% terbuthylazine + 15% terbumeton + 20% terbutryn, with 1.25–5.5 kg glyphosate, and with 1.25 kg sulfosate [trimethylsulfonium carboxymethylaminomethyl phosphonate] and glufosinate; prospects for the control of this weed in Spanish *Citrus* spp. orchards are discussed in the light of these findings.

47. Gomez de Barreda D, Lorenzo E 1989. Some data on the comparative activity of glyphosate, glufosinate and sulfosate. Proceedings of the 4th EWRS symposium on weed problems in Mediterranean climates. Vol. 2. Problems of weed control in fruit, horticultural crops and rice. Pp. 243–251.
In trials to compare the activities of glyphosate, glufosinate and sulfosate (trimethylsulfonium carboxymethylaminomethyl phosphonate) against *Araujа sericofera* and using oat bioassays, few significant differences between the compounds were evident. Droplet spectra of controlled droplet application sprays of these herbicides were markedly different.

Asparagus asparagoides

48. Turner PJ, Virtue JG 2009. Ten year post-fire response of a native ecosystem in the presence of high or low densities of the invasive weed, *Asparagus asparagoides*. Plant Protection Quarterly 24(1): 20–26.
Bridal creeper, *Asparagus asparagoides* (L.) Druce, is a major environmental weed in southern Australia. Being a geophyte, it has annual shoot growth with a large tuberous root mat below ground. It is capable of displacing native vegetation and has been targeted for control in Australia, especially using biological control. Previous studies on the impact of this environmental weed have suggested that, without further restoration, invaded areas could take many years to recover. As fire can be used as a restoration tool, given it can stimulate the regeneration of some native Australian plants, this study aimed to determine the response of a native plant community for the first 10 years following a fire, with and without the presence of bridal creeper. Following a wildfire in March 1996, plots were established in a mallee remnant in South Australia. In October 1996, bridal creeper was controlled in half the plots using glyphosate. In 2006, there was still a significant difference in the density of bridal creeper, with 33.4 ± 5.0 (mean ± SE) emerging shoots/m^2 in the untreated plots compared with 9.1 ± 1.2 shoots/m^2 in the controlled plots. However, at the same time, there was no significant difference in the native plant assemblages or with the number of native plant species between plots with high or low density of bridal creeper, except for small shrubs, creepers and climbers, which had higher cover in the untreated plots. A difference in soil nutrients was also evident. The soil where bridal creeper was not controlled had significantly higher ammonium, potassium and organic carbon, compared with where bridal creeper was controlled. This study site, in the early stages of post-fire succession, appears to be resilient to the impacts of bridal creeper and other weed species, with acacias and other native trees and shrubs dominating the site. It is therefore concluded that fire can be an important restoration tool to stimulate the regeneration of some native Australian plants and speed up the recovery of bridal-creeper-invaded ecosystems, provided that bridal creeper and other weeds are kept at a low post-fire density, naturally or through targeted control.

49. Turner PJ, Virtue JG 2006. An eight year removal experiment measuring the impact of bridal creeper (*Asparagus asparagoides* (L.) Druce) and the potential benefit from its control. Plant Protection Quarterly 21(2): 79–84.
Bridal creeper, *Asparagus asparagoides* (L.) Druce, is a weed with climbing annual shoot growth and extensive, underground storage tubers, and is capable of dominating native vegetation. While its impacts appear obvious, this has been measured in few quantitative studies. In 1996, 40 3 × 3 m plots were established in a mallee remnant north of Adelaide, South Australia, to investigate this issue. Using glyphosate, bridal creeper was removed from half the plots in 1997, with follow-up treatment for the same plots in 1999. In 2005 there was still no significant difference in the number of native plant species between plots with or without bridal creeper. There was also no significant difference in abundance of individual

native species, except for the saltbush *Enchylaena tomentosa* ($P < 0.01$). However, there were consistent increases in cover of the chenopod and native grass understorey in the bridal-creeper-removed plots, even if not significant for some species. The common chenopods *E. tomentosa* and a combined dataset for *Rhagodia parabolica* and *R. candolleana* had greater shoot biomass where bridal creeper had been controlled ($P < 0.01$ and $P < 0.05$ respectively). An exotic plant, *Oxalis pes-caprae*, also had higher cover in plots without bridal creeper compared with untreated plots ($P < 0.01$). This study has shown that it may take many years for recovery following weed control and additional restoration work may be necessary. Dead tubers were still intact below the surface in the removal plots and their presence may be affecting seedling establishment. Recovery may also have been hindered by higher *O. pes-caprae* density. A third possibility is a lack of suitable environmental conditions in the 8-year period for germination and establishment of indigenous species.

50. Meney K, Dixon B, et al. 2002. Control of bridal creeper *Asparagus asparagoides* on Kings Park Scarp and limiting factors on its growth and spread. In: Jacob HS, Dodd J, Moore JH eds 13th Australian Weeds Conference. Plant Protection Society of Western Australia Inc. Pp. 113–116.

The dominant weed along the Kings Park limestone escarpment in Perth, Western Australia, is *A. asparagoides*, a South African rhizomatous geophyte. A 3-year (1997–2001) research programme was initiated to establish limiting factors affecting its growth and spread, and to determine control measures. Research indicated that the preferred habitat of bridal creeper is characterised by high soil and litter moisture content and low light intensity, which equates to a longer growing and reproductive season. Disturbed and native habitats with high shade factors are ideal for establishing new populations and subsequent spread. Opening up the canopy to increase light levels above 1000 micro mol/s/m^2 significantly reduces its invasive capacity and assists the establishment of native understorey species. Some knowledge on the control of bridal creeper in Kings Park bushland had been established as early as 1991. Further trials conducted in 1997 in late autumn, winter and early spring were designed to establish if a range of non-selective herbicides at low rates would kill bridal creeper without too much off-target damage to indigenous species. Brushoff (600 g/kg metsulfuron-methyl [metsulfuron]) achieved the best results overall. When sprayed in July at a rate of 1 or 2.5 g/ha up to a 100% reduction in above-ground biomass of bridal creeper was recorded with little off-target damage. The results also indicated a much larger window of opportunity (May–July) when spraying at the higher rate of 2.5 g/ha. Implementing these results on an operational scale has resulted in high death rates and reduced the estimated above-ground biomass of bridal creeper on the scarp by 85%.

51. Pritchard GH 2002. Evaluation of herbicides for the control of the environmental weed bridal creeper (*Asparagus asparagoides*). Plant Protection Quarterly 17(1): 17–26.

Five herbicide trials were conducted on the environmental weed bridal creeper (*Asparagus asparagoides*) growing in native vegetation in southern Victoria, Australia. Glyphosate at 180 g and 360 g/100 L and metsulfuron-methyl [metsulfuron] at 1–6 g/100 L applied in winter–spring gave 88–99.5% control of above-ground growth after 1 year and 87–94% control 2 years after application. Re-application 1 or 2 years after an initial application increased this control to 91–99%. Control of above-ground growth with either herbicide was little affected by concentration. Glyphosate had more effect on the root system than metsulfuron-methyl. A single application of glyphosate at 180 g/100 L reduced the root system by 78%, while 1 year after a repeat application, this concentration reduced the root system by 90–99%. Glyphosate at 360 g/100 L reduced the root system by 95% after a single application and two applications did not improve on this result. A single application of metsulfuron-methyl at 1.5 g/100 L reduced the root system by 32% but 3 g/100 L gave no reduction. One year after a repeat application at 1.5, 3 and 6 g/100 L, root reductions were 41–92%, 29–53% and 74% respectively. Control with both herbicides was better with August application (flowering) than with July (flower bud) or October (green berries) application. Chlorsulfuron and a commercial mix of thifensulfuron methyl + metsulfuron-methyl gave effective foliage control but offered no improvement over metsulfuron-methyl in root control. Tribenuron methyl gave less foliage control than the other herbicides.

52. Dixon IR 1996. Control of bridal creeper (*Asparagus asparagoides*) and the distribution of *Asparagus declinatus* in Kings Park bushland, 1991–1995. Plant Protection Quarterly 11(2): 61–63.

The results are presented of trials studying the control of bridal creeper (*Asparagus asparagoides*) with glyphosate (Roundup®), metsulfuron-methyl (Brushoff®) and sulfometuron-methyl (Oust®) alone or in combination, glyphosate + or − penetrant (Pulse®) or wetting agent (DC Trate®), and metsulfuron-methyl (Ally®) + Pulse or wetting agent (BS 1000®). A distribution map is provided for *A. declinatus*, and its spread within Kings Park and the Botanical Garden is outlined.

53. Pritchard GH 1996. Bridal creeper control with herbicides. In: Shepherd RCH ed. Proceedings of the 11th Australian Weeds Conference, Melbourne, Australia, 30 September – 3 October 1996. Pp. 424–427.

Bridal creeper (*Asparagus asparagoides* (L.) W. Wight), native to southern Africa, is a garden escape that is invading bushland in southern Australia. Two trials on bridal creeper growing in bushland in southern Victoria commenced in October 1994. The bridal creeper had finished flowering and was covering the ground and climbing on trees and shrubs to a height of 2.5–3 m. The spray volume was 1000 L/ha in Trial 1, and 700 L/ha in Trial 2. One year after application in Trial 1, glyphosate at 180 g/100 L, chlorsulfuron at 1.9 g/100 L, metsulfuron-methyl at 1.5 g/100 L, thifensulfuron methyl/metsulfuron-methyl at 15/1.5 g/100 L, and a tankmix of glyphosate + metsulfuron-methyl at 90 g + 1.5 g/100 L gave 91.94% control. Higher rates of glyphosate (360 g/100 L), metsulfuron-methyl (6 g/100 L) or glyphosate + metsulfuron-methyl (180 g + 3 g/100 L) did not improve on these results. In Trial 2, glyphosate at 180 g/100 L, metsulfuron-methyl at 1.5 g/100 L, thifensulfuron methyl/metsulfuron-methyl at 15/1.5 g/100 L, and glyphosate + metsulfuron-methyl at 90 g + 1.5 g/100 L gave 88.93% control 1 year after application. Tribenuron methyl at 15 g/100 L gave only 64% control. No significant increase in control was obtained by applying higher rates of glyphosate (360 g/100 L) or metsulfuron-methyl (3 g/100 L), or by applying metsulfuron-methyl at 1.5 g/100 L in a higher spray volume of 1000 L/ha.

54. Earl J 1994. Boneseed and bridal creeper control in native vegetation. In: Carter RJ ed. Managing weeds for landcare 1994. SA Animal and Plant Control Commission. P. 7.

In field trials conducted by the Department of Environment and Natural Resources, commencing in the mid-1980s, the effects were evaluated of various herbicides for the control of boneseed (*Chrysanthemoides monilifera* subsp. *monilifera* [*C. moniliferum* ?]) and bridal creeper [*Myrsiphyllum asparagoides*] plants. Glyphosate (360 g/L), used as a foliar spray at strengths ranging from 1:400 to 1:100, controlled boneseed plants to varying degrees depending on the concentration used. Higher concentrations were required to control larger boneseed plants. Damage to native vegetation varied according to the mixture strength and density of boneseed plants; the higher concentration damaged more native plants, while high boneseed plant densities reduced native plant damage. Metsulfuron-methyl at 10 g/100 L resulted in the greatest control of bridal creeper. Damage to the native vegetation was minimised due to the canopy effect created by heavy infestations of bridal creeper. The kill rate on bridal creeper was, in most cases, >90%.

55. McQuinn DJ 1994. Chemical control of bridal creeper in South Australia. Results of field trials on Yorke Peninsula and upper S.E. In: Carter RJ ed. Managing weeds for landcare 1994. SA Animal and Plant Control Commission. P. 6.
In field trials conducted at Minlaton, South Australia, during 1989–91, the effects were evaluated of Brushoff (metsulfuron-methyl) at 5 g/100 L for the control of bridal creeper [*Myrsiphyllum asparagoides*]. Brushoff resulted in 85–95% control of *M. asparagoides* 12 months after spraying, irrespective of spray timing. However, after this period, Brushoff-treated areas became infested with seedling *M. asparagoides* plants. It was suggested that a follow-up treatment is needed. No benefit was obtained from spraying at higher concentrations than 5 g. Brushoff had some soil residual activity, with its degradation being dependent on the concentration applied, soil pH, and rainfall. The standard surfactant BS1000 at 100 ml/100 L was recommended for use with Brushoff.

56. Pitchard GH 1991. Control of bridal creeper with herbicides. Plant Protection Quarterly 6(3): 126.
In field trials at Wail State Forest in 1989 with September spraying of herbicides onto bridal creeper (*Myrsiphyllum asparagoides*), the most effective control (90–99%) was obtained with metsulfuron-methyl + Agral 600 at 6–12 g/100 L 0.7% v/v, glyphosate + Pulse at 180 g + 0.2%, glyphosate + metsulfuron at 360 + 3 g, respectively, and triclopyr/picloram at 75/25 g. Less control (85%) was obtained with 2,4-D/picloram at 200/50 g and amitrole at 500 g. Addition of the surfactants Pulse, Tregspray and Wetter TX had no significant effects. Fluroxypyr at 400 g alone or + 2% crop oil and MCPA/diflufenican at 500/50 g were ineffective. In further trials in 1990 at Point Nepean, October application of 180 g of glyphosate was as effective as 360 g at controlling *M. asparagoides* and addition of Pulse did not improve the control. Glyphosate gave more effective control than triclopyr at 480 g or 6–metsulfuron + Pulse or BS100 at 3 g + 2% and at 6 g + 2% gave 85–95% and 95–98% control, respectively, of *M. asparagoides* 1 year after treatment. Glyphosate + Pulse at 360 g + 0.2% resulted in 65–70% control. Chemical control of *M. asparagoides* was also evaluated in pot trials; the results indicated that the weed was more sensitive to sulfonylurea herbicides than to glyphosate although efficacy of the latter was increased by addition of Pulse.

Celastrus orbiculatus

57. Ward B, Henzell R 2003. A novel herbicidal gel technique for controlling the vine *Celastrus orbiculatus* (climbing spindleberry). In: Child L, Brock JH, Brunduet G, et al. eds Plant invasions. Backhuys. Pp. 331–336.
Invasive weed vines such as *Celastrus orbiculatus* Lam. (climbing spindleberry), *Clematis vitalba* L. (old man's beard) and *Lonicera japonica* Thunb. (Japanese honeysuckle) are major threats to biodiversity and ecological processes in New Zealand native parks and reserves. These vigorous weeds are smothering or preventing the establishment and growth of native flora. Traditional weed management strategies for these weeds have depended on foliar application of herbicides, manual pruning, or plant removal. These techniques are either not completely effective or have off-target effects on adjacent native plant species. HortResearch has developed herbicidal gel techniques for the selective eradication of these invasive weeds. This paper outlines the successful cut-stem treatment and efficacy of the herbicidal gel

Vigilant® for eradicating weed vines such as *C. orbiculatus* growing among native bush canopies without affecting neighbouring species. In areas where tile vine is growing through or is covered by scrub like *Rubus fruticosus* L. (blackberry) or *Pteridium esculentum* Cockayne (bracken) it is more practical to spray these areas first with a foliar application of herbicide and then follow up annually with cut-stem treatments with Vigilant gel to any weed seedling growing up through the dead scrub.

58. Dreyer GD 1988. Efficacy of triclopyr in rootkilling oriental bittersweet (*Celastrus orbiculatus* Thunb.) and certain other woody weeds. Proceedings, 42nd annual meeting of the Northeastern Weed Science Society: 120–121.
Triclopyr evaluated as a salt and ester formulation (3 and 4 lb/gallon, respectively) and as an ester 1 lb/gallon + 2,4-D 2 lb/gallon controlled *C. orbiculatus* 1 year after treatment, but failed to control *Lonicera japonica* and *Euonymus alatus*. Subsequent use of triclopyr ester and salt formulations in arboretum landscape renovations confirmed their effectiveness against *C. orbiculatus*. Triclopyr also controlled Rubus hispidus and *Parthenocissus quinquefolia*.

Clematis vitalba

59. Dixon FL, Clay DV, et al. 2006. The efficacy of pre-emergence herbicides on problem weeds in woodland regeneration. Crop Protection 25: 259–268.
Weeds germinating from seed are serious competitors for resources with young trees and can delay or prevent woodland establishment and regeneration. However, there is only limited information available on which pre-emergence herbicides are effective on problem weeds that commonly occur in these situations, in particular for perennial species germinating on fertile ex-agricultural sites. Following previously reported glasshouse screening experiments for potentially useful herbicide treatments, 10 residual herbicide treatments were tested on 12 problem weed species in the field. The results showed considerable variations in the susceptibilities of weed species to the different herbicide treatments. The combination of atrazine + cyanazine, included as a standard herbicide mix that is commonly used in forestry situations, was the most effective treatment overall, with most weed species appearing to be susceptible or moderately susceptible. *Chamerion angustifolium* (rosebay willowherb) was the most sensitive species tested, being well controlled by the mixture of atrazine + cyanazine, metazachlor, the higher doses of napropamide, and the mixture of metazachlor + pendimethalin. *Cirsium arvense* (creeping thistle) was susceptible to isoxaben, and atrazine + cyanazine. *Clematis vitalba* (old man's beard) was susceptible to isoxaben. *Senecio vulgaris* (groundsel) was well controlled by atrazine + cyanazine, and metazachlor. *Ranunculus repens* (creeping buttercup) only appeared to be controlled by napropamide. *Rumex obtusifolius* (broadleaved dock) and *Urtica dioica* (common nettle) were susceptible to pendimethalin. *Rubus fruticosus* agg. (bramble), *Cirsium vulgare* (spear thistle), *Senecio jacobea* (common ragwort) and Trifoli*um repens* (white clover) were only susceptible to the mixture of atrazine + cyanazine. *Brassica napus* ssp. *oleifera* (volunteer oilseed rape) was not completely controlled by any of the treatments, although atrazine + cyanazine did give significant growth reductions. A comparison of the susceptibility implied by existing literature, glasshouse pot experiments, and the field trials reported here shows the importance of confirming results obtained in pot trials with field testing and provides valuable information on efficacy, which will be useful in assisting herbicide selection in the future.

60. Clay DV, Dixon FL 2000. Further investigations on the control of *Clematis vitalba* (old man's beard). Aspects of Applied Biology 58: 71–76.

Clematis vitalba chemical control was investigated in field experiments held between 1993 and 1996 in Hampshire, UK. The effects of the herbicide treatments in six separate experiments on *C. vitalba* green cover are tabulated. Imazapyr as a summer spray to foliage on fence lines, or as a late winter spray on cleared areas gave complete long-term control of *C. vitalba*. Glyphosate and metsulfuron-methyl [metsulfuron] applied to foliage in summer were less effective. Application of clopyralid or tribenuron-methyl [tribenuron] ± surfactant as selective treatments for *C. vitalba* control in hedges in summer reduced growth in the year of application, but had no long-term effect. Spraying of imazapyr on small areas of *C. vitalba* at the centre of infestations killed treated shoots; growth was reduced up to 3 m away the following year and stems near the sprayed area were killed. However, the cleared area was completely recolonised from adjacent plants the following year. No adverse effects were observed on any woody hedgerow species present (including *Rubus fruticosus*, *Rosa canina* and *Crataegus oxycanthoides*) from any of the treatments tested for selective control.

61. Ward BG, Henzell RF 2000. Herbicide gels for controlling old man's beard (*Clematis vitalba*) in ecologically sensitive areas. In: Zydenbos SM ed. Proceedings of a conference, Commodore Hotel, Christchurch, New Zealand, 8–10 August 2000. New Zealand Plant Protection 53: 284–288.

Old man's beard (*C. vitalba*) is a significant environmental weed and can completely smother the growth of native vegetation in many New Zealand parks and reserves. Current herbicide application techniques are either not effective on the weed or can have non-target effects on the adjacent native plant species. HortResearch has developed herbicidal gels for the direct application to cut stems to selectively kill target plants. The gels were formulated with a range of active ingredients. The efficacy of the gel formulation of the herbicides picloram, Tordon 50-D 1, triclopyr, metsulfuron, sodium chlorate and phosphorous acid was tested in field experiments conducted in Taihape Scenic Reserve in New Zealand on 27 and 28 November 1995 and 30 August 1996. Picloram-based gels were the most effective treatments on old man's beard without causing any non-target effects.

62. Clay DV, Dixon FL 1996. Investigations of control methods for *Clematis vitalba* (old man's beard). Aspects of Applied Biology 44: 313–318.

Clematis vitalba occurs on base-rich soils in central and southern England and can seriously damage growth of hedges and small trees. Repeated cutting does not eradicate it and there are no recommendations for its control by herbicides. In pot experiments glyphosate and imazapyr were the most effective of 13 herbicides applied to growing plants. In field experiments at Damerham, Hampshire, in which herbicides were applied to *C. vitalba* on a fence line in summer, imazapyr eradicated all plants; metsulfuron-methyl was more effective than glyphosate or triclopyr. Applications of imazapyr to cut stumps in later winter prevented any regrowth; triclopyr was less effective; and metsulfuron-methyl had no effect. There is a need for further research to develop appropriate control measures for this invasive plant in the variety of habitats where it is a problem.

63. Britt CP 1994. *Clematis vitalba* (old man's beard) as a competitive "weed" in hedgerows and the effects of hedge cutting regimes on its development. In: Boatman N ed. Field margins. Proceedings of a symposium held at Coventry, UK, 18–20 April 1994. British Crop Protection Council (BCPC). Pp. 241–246.

Clematis vitalba is a woody, climbing plant commonly found on calcareous soils in the Midlands and south of England. Unless it is controlled by management practices, it is capable of smothering hedges. An experiment at Stratford-upon-Avon, Warwickshire, examined the effects of four hedge-management techniques (cutting both sides and the top of the hedge annually to form a rectangular shape with a height of 1.4 m with, or without, hand cutting *C. vitalba* stems and treating the stumps with glyphosate; cutting alternate sides and top of the hedge annually to form a rectangular shape with a height of 1.4 m; and cutting both sides annually to from a A-shape with a height of 1.8 m) for the control of *C. vitalba* in a hawthorn [*Crataegus laevigata*] hedge. Cutting *C. vitalba* stems at their base and treating the stumps with glyphosate resulted in effective control of this species, with a consequent improvement in hedge density and height. The method of mechanical hedge trimming had no clear short-term effect on *C. vitalba* abundance.

64. Downard P 1986. Herbicides for control of old man's beard. Proceedings of the thirty-ninth New Zealand Weed and Pest Control Conference: 108–109.
In trials in Canterbury, Nelson and Manawatu, 17 g picloram + 68 g 2,4,5-T or triclopyr/10 L spray applied by knapsack sprayer to the lower 2 m of tree stems gave complete control of *Clematis vitalba*, effectively releasing trees from competition. Excellent control was also provided by picloram + 2,4,5-T at 11 + 44 g and 22 + 88 g, 200 and 300 g clopyralid and 120, 240 and 360 g glyphosate all in 100 L of spray and applied to run-off at 4000 L/ha up to 4 m high. In two trials in which herbicides were applied by helicopter using standard disc and core nozzles and the half overlapping double pass technique, picloram + 2,4,5-T at 0.6 + 2.4 kg or 1.3 + 5 kg and 3.8 or 7.5 kg clopyralid, all in 220 and 440 L/ha, gave 60–90% and 30–80% control, respectively It is suggested that clopyralid, since it is tolerated by a large number of introduced trees and shrubs, would be suitable for use in amenity areas, while where directed basal application is feasible, picloram + 2,4,5-T or + glyphosate could be used around those woody species that would not tolerate overall sprays.

65. Ryan C 1985. Pests and problems – old man's beard. Soil & Water 21(3): 13–17.
Problems of infestations of *Clematis vitalba* in forests, along rivers and in urban areas of New Zealand and methods of control, including the use of glyphosate, are discussed.

Hedera helix

66. Derr JF 1993. English ivy (*Hedera helix*) response to postemergence herbicides. Journal of Environmental Horticulture 11(2): 45–48.
One application of Roundup at 2.2 or 4.5 kg ai/ha (2.0 or 4.0 lb/acre) with or without surfactant, Weedar 64 (2.4-D amine) at 1.1 kg/ha ae (1.0 lb/acre), Banvel at 0.6 kg/ha ae (0.5 lb/acre), or Garlon 3A at 0.6 kg/ha ae (0.5 lb/acre) reduced new shoot growth of English ivy 10 weeks after treatment by 46–80%. Roundup at 4.5 kg/ha + non-ionic surfactant was the only single-application treatment that reduced older shoot growth of English ivy (41% reduction) 19 weeks after treatment. English ivy outgrew injury from all other single-application treatments. Two applications of Weedar 64 completely controlled English ivy. Two applications of Roundup at 4.5 kg/ha (4.0 lb/acre), with or without surfactant, eliminated new shoot growth 11 weeks after treatment, and reduced total shoot weight by approximately 60% 15 weeks after treatment. English ivy shoot weight decreased when the rate of Roundup was increased from 2.2 to 4.5 kg/ha (74% versus 92% reduction) 7 weeks after treatment, but adding a non-ionic surfactant did not further reduce shoot weight. Two applications of Banvel or Garlon (52% and 67% reduction, respectively, 7 weeks after treatment) were less effective than two applications of Roundup at 4.5 kg/ha (4.0 lb/acre) in reducing English ivy shoot growth.

67. Hield H 1986. PGR product comparisons for effectiveness on ivy, oleander and privet. Plant Growth Regulator Bulletin 14(4): 5–7.

In trials at various sites, established hedges of *Hedera helix*, *Nerium oleander* and *Ligustrum japonicum* were sprayed to run-off with maleic hydrazide (MH), chlorflurenol [chlorflurecol], flurprimidol, dikegulac, paclobutrazol or mefluidide. The rates and compounds used varied with the trials. With *Hedera helix*, growth control with dikegulac (0.4%), flurprimidol (0.3 or 0.4%), paclobutrazol (0.3%) and chlorflurenol (0.03%) lasted for about 5 months. With MH (0.5%) and mefluidide (0.3%), the number of new shoot breaks was reduced for up to 3 months and shoot length was reduced for a month, compared with unsprayed controls. In a commercial-type trial, chemical control of growth for a year required only 4.3 h labour and 2 quarts of Maintain CF125 (0.12% chlorflurenol), whereas manual control required 10.9 h labour. With *Nerium oleander*, flurprimidol (0.3%) and dikegulac (0.3%) were the most effective (up to a year in some trials), with MH (0.5%) and chlorflurenol (0.12%) giving control for at least 2 months. MH gave better control than dikegulac in one trial; the formulation used affected results, and some shoot tip injury and chlorosis resulted from one type, possibly due to the carrier. With *Ligustrum japonicum*, flurprimidol (1.5%) gave a 34% reduction in shoot length and 69% reduction in weight of prunings more than a year after treatment. Even after 2 years, growth was markedly inhibited. Mefluidide checked growth for 54 days when applied at 0.12% and for 111 days at 0.24%. Chlorflurenol (0.12%) and paclobutrazol (0.3%) gave some control, but MH was not effective.

68. Kafadaroff G, Brunet Y, et al. 1977. Outcome of 6 years' experimentation with glyphosate in tree fruits, Compte Rendu de la 9e Conférence du COLUMA (Comité français de lutte contre les mauvaises herbes): 645–655.

Control of weeds in tree fruits is substantially similar to that reported for vines. However, *Cynodon dactylon* grows more vigorously in orchards due to fertilisation and irrigation; reinfestation is therefore more rapid than in vineyards. *Convolvulus* [= *Calystegia*] *sepium* is well controlled with glyphosate at 3.6 kg/ha, but regrowth is considerable. As in vineyards *Equisetum arvense*, *Hedera helix* and *Rubia peregrina* are resistant to glyphosate. The best treatment times for various weeds are listed, together with herbicide rates required. For mixed infestations of annual and broadleaved weeds glyphosate at 2.88 kg/ha should be applied ± simazine; the rate should be increased to 4.32 kg/ha if *Cynodon dactylon* is present. In 1977, evaluation trials were carried out with glyphosate in young fruit trees; symptoms of toxicity as a result of accidental contact of the tree leaves with glyphosate are listed. Applications to the base of fruit trees, or on rootstock shoots, only cause injury if the trees have wounds due to recent pruning or debudding. Control of rootstock shoots with a solution of 1%, 2.5% or 5% of the formulated product is very good.

Lonicera japonica

69. Larson BMH, Catling PM, et al. 2007. The biology of Canadian weeds. 135. *Lonicera japonica* Thunb. Canadian Journal of Plant Science 87: 423–438.

Japanese honeysuckle (*Lonicera japonica* Thunb.) is a twining semi-evergreen vine native to Japan, Korea and eastern China. Over the past 150 years it has been introduced as an ornamental and become established in temperate and tropical regions worldwide. It was first discovered in Canada in 1976 in south-western Ontario woodlands and has since been found growing without cultivation in 15 localities. While *L. japonica* does not occur very frequently in southern Ontario, climate change models suggest that it may become more abundant in this region. Its predominance elsewhere derives from morphological and physiological characteristics that allow it to be particularly successful in the edge habitats of fragmented landscapes. Through extensive vegetative propagation and competitive ability it occupies space that may otherwise host a diverse native flora. The plant has many uses in Asian medicine and is a popular ornamental, but has been prohibited in some regions due to its displacement of other species. A combination of cutting and foliar application of glyphosate has proven to be an effective control method in some circumstances. Planting of *L. japonica* should be discouraged and horticulturalists should consider alternative attractive vines. The spread of *L. japonica* should be monitored in Ontario and control of newly established populations should be considered to avoid costly large-scale control in the future.

70. Williams PA, Timmins SM, et al. 1998. Control of Japanese honeysuckle (*Lonicera japonica*), climbing dock (*Rumex sagittatus*), and bone-seed (*Chrysanthemoides monilifera*). Science for Conservation 100. Wellington, Department of Conservation. 15 p.

Three weeds of high conservation concern – *Lonicera japonica*, *Rumex sagittatus* and C*hrysanthemoides monilifera* – were sprayed with a range of herbicides at sites in New Zealand. *L. japonica* was treated with glyphosate (1 L/100 L water), triclopyr (300 ml/100 L), clopyralid (500 ml/100 L) and metasulphuron [metsulfuron] (35 g/100 L), *R. sagittatus* was sprayed with metsulfuron (10 g/100 L), and *C. monilifera* was treated with triclopyr (6 ml/100 L). The three weeds, and their associated native vegetation, were monitored to determine their response after control. *L. japonica* was initially controlled, but some plants showed signs of recovery from vegetative parts. No *L. japonica* seedlings emerged and native species recovered by vegetative means. Most *R. sagittatus* was killed by spraying, as well as a small proportion of the associated native vegetation. Sprayed *R. sagittatus* plants failed to regenerate, but new plants emerged from seed. The native vegetation showed signs of recovery. Sprayed *C. monilifera* plants were killed, as were a few native plants that were inadvertently sprayed. However, by the spring following the spraying, *C. monilifera* seedlings were common. By the following winter, *C. monilifera* seedlings and small plants were abundant, many of them flowering. There was no similar flush of seedlings of native species.

71. Yeiser JL, Howell RK 1997. Honeysuckle control in a minor hardwood bottom of southwest Arkansas. In: Dusky JA ed. Fifty years of weed science. Southern Weed Science Society: Proceedings Southern Weed Science Society, 50th annual meeting, Houston, Texas, USA, 20–22, January 1997. Pp. 105–108.

Field trials were conducted in south-west Arkansas to assess the efficacy of foliar applications of 0.5–1.5 ounces/acre Escort (metsulfuron), 1.0 pints[8] Tordon K (picloram) + 1.0–2.0 pints Garlon 3A (triclopyr), 1.3 pints Transline [clopyralid + 2,4-D] and 1.5% v/v Accord (glyphosate) applied in June for control of *Lonicera japonica* in a 4-year-old *Quercus* spp. clearcut stand and in a mixed *Quercus*, *Carya* and *Fraxinus* stand of 30- to 40-year-old trees. Results indicated that best control of *L. japonica* with minimum damage to *Quercus* was achieved with 0.5 ounces Escort in the young stand, while 1.5% Accord and 0.5–1.5 ounces Escort gave best results in the mature stand.

72. Miller JH 1995. Exotic plants in southern forests: their nature and control. In: Street JE ed. Herbicide-resistant crops. Southern Weed Science Society. Pp. 120–126.

The nature and control of exotic species in forests of the southern USA are reviewed. Various aspects of the problem are reviewed, including the ecology, origin, range, uses and herbicidal

[8] 1 pint = 0.568 litre

control of 16 of the most prevalent exotic trees, shrubs, vines and grasses (*Albizia julibrissin*, *Melia azedarach*, *Sapium sebiferum*, *Lespedeza bicolor*, *Ligustrum japonicum*, *L. sinense*, *Rosa multiflora*, *Lonicera japonica*, *Lygodium japonicum*, *Pueraria lobata*, *Wisteria sinensis*, *Cynodon dactylon*, *Digitaria* spp., *Imperata cylindrica* and *Sorghum halepense*). Integrated weed control is recommended, with a biological control component.

73. Yonce MH, Skroch WA 1989. Control of selected perennial weeds with glyphosate. Weed Science 37: 360–364.
The efficacy of glyphosate as affected by rate, time of application, and addition of surfactant was evaluated on blackberry, Japanese honeysuckle, poison ivy, *Sericea lespedeza*, and trumpetcreeper. The addition of surfactant (0.5% v/v) to glyphosate had no effect on the control of the weeds studied. Glyphosate applied in mid-June to September at 1.1 or 2.2 kg/ha controlled blackberry. Mid-August glyphosate applications of 2.2 kg/ha controlled 83% of actively growing Japanese honeysuckle; there was less than 75% at one site due to moisture stress. Use of 2.2 kg/ha of glyphosate from mid-June through mid-August controlled 87% of poison ivy. Consistent commercially acceptable control of *Sericea lespedeza* was obtained when glyphosate was applied at 1.1 or 2.2 kg/ha at the time of flowering. Applying glyphosate at 1.1 or 2.2 kg/ha from late July through early October controlled 50% or more of the trumpetcreeper.

74. Regehr DL, Frey DR 1988. Selective control of Japanese honeysuckle *Lonicera-Japonica*. Weed Technology 2: 139–143.
Japanese honeysuckle (*Lonicera japonica* Thunb. #3 LONJA) vines can smother young trees, presenting problems in nursery, parkland, and woodlot management. The tardy-deciduous nature of honeysuckle provides an application window for its selective control with glyphosate [N-(phosphonomethyl)-glycine] or dichlorprop [(±)-2-(2,4-dichlorophenoxy)propanoic acid] + 2,4-D [(2,4-dichlorophenoxy)acetic acid] immediately after fall defoliation of hardwood species. Glyphosate at 1.5% v/v (ae at 5.4 g /L) applied in December killed mature, woody honeysuckle vines and eliminated most regrowth from basal and subterranean buds 28 months after treatment. Dichlorprop + 2,4-D at 1.5% v/v (ae at 3.6 g /L of each herbicide), when applied shortly after the first freezing temperatures in October, was as effective as glyphosphate but was less effective when applied in December. Tuliptree (*Liriodendron tulipifera* L.), American beech (*Fagus grandifolia* Ehrh.), and Scotch pine (*Pinus sylvestris* L.) suffered minimal and temporary injury from these herbicides.

75. Edwards MB, Gonzalez FE 1986. Forestry herbicide control of kudzu and Japanese honeysuckle in loblolly pine sites in central Georgia. Proceedings, Southern Weed Science Society, 39th annual meeting: 272–275.
Control of kudzu (*Pueraria lobata*) was 99% with 0.5–2 lb metsulfuron-methyl/acre + 0.25% surfactant, applied in May; similar control of Japanese honeysuckle (*Lonicera japonica*) was obtained with 2 oz metsulfuron-methyl + 0.25% surfactant. Both young and mature *Pinus taeda* tolerated these treatments.

76. Ahrens WH, Pill WG 1985. Gel-incorporated glyphosate for perennial weed control. Hortscience 20: 64–66.
Herbicidal efficacy of 0, 1, 4, 7 and 10% Roundup incorporated in carboxymethyl cellulose (CMC) and starch-grafted polymer (SGP) gels was evaluated after topical application (2 ml gel/plant) to leaves of Canada thistle [*Cirsium arvense*], field bindweed [*Convolvulus arvensis*] and Japanese honeysuckle [*Lonicera japonica*]. Increasing Roundup concentration caused a quadratic injury rating response in Canada thistle, with 7% Roundup giving

maximal injury. Complete shoot necrosis and minimal regrowth of field bindweed resulted from 4, 7, or 10% Roundup. Injury ratings in Japanese honeysuckle increased linearly with increasing Roundup concentration, although no concentration gave complete control with one application. After a second application, complete shoot necrosis occurred in only 50% of the plants treated with 10% Roundup. Although efficacy of gel-incorporated Roundup was not appreciably affected by gel type, SGP shelf life at room temperature was superior to that of CMC.

77. McLemore BF 1982. Comparison of herbicides for controlling hardwoods in pine stands. Proceedings 35th Annual Meeting Southern Weed Science Society: 195–199.
A 4:1 mixture of 2,4-D + picloram applied as a foliar spray at 2.8–8.4 kg/ha gave 84–94% control of a hardwood understorey in a loblolly (*Pinus taeda*) and shortleaf pine (*P. echinata*) stand. Other herbicides were less effective but 2.24 and 4.48 amitrole/ha was as active as the mixture against *Lonicera japonica*.

78. McLemore BF 1981. Evaluation of chemicals for controlling Japanese honeysuckle. Proceedings 34th Annual Meeting Southern Weed Science Society: 208–210.
Foliage sprays of glyphosate, aminotriazole, hexazinone and 2,4-D + dichlorprop (1:1) were applied at 2.24, 4.48 and 6.72 kg/ha to control Japanese honeysuckle (*Lonicera japonica*) in a stand of *Pinus taeda* and *P. echinata* in south-east Arkansas. All rates of glyphosate and 2,4-D + dichlorprop gave acceptable control during the first year of treatment. After 2 years only the 4.48 and 6.72 kg/ha rates of aminotriazole and the 6.72 kg'ha rate of glyphosate continued to be satisfactory.

Macfadyena unguis-cati

79. Lu C-Y, Zhang M-Q, et al. 2006. Study on glyphosate applied technology in controlling invasive plant *Macfadyena unguis-cati* (L.) A. Gentry, in Xiamen. Xiamen Daxue Xuebao 45(1): 136–140.
Plant growth cabinet experiments were carried out under controlled conditions to test herbicide effects on the germination of *Macfadyena unguis-cati* (L.) A. Gentry seeds by spraying glyphosate at different concentrations. Results show that *M. unguis-cati* seeds could be killed by spraying with 0.1% glyphosate before germination. Experiments have also been done using glyphosate to control *M. unguis-cati* in *Acacia* forest near Xiamen University that is damaged by *M. unguis-cati*. Results with 0.1% glyphosate were similar to with 0.5% concentration and glyphosate could be foliar-sprayed in areas where *M. unguis-cati* does not cause great harm. After hand control, some regrowth is likely to occur. Any regrowth can be foliar sprayed with 0.1% or 0.5% glyphosate also. In areas where *M. unguis-cati* has caused greatest harm or made large infestations, 1.0% glyphosate could be foliar-sprayed to great effect on the roots. The stems of individual vines with a diameter greater than 0.4 cm could be cut close to the ground and the basal end covered with cotton dipped in 10% glyphosate for 2 h. Use of these methods can effectively control damage by *M. unguis-cati*.

80. Singh S, Singh M 2004. Effect of growth stage on trifloxysulfuron and glyphosate efficacy in twelve weed species of citrus grove. Weed Technology 18: 1031–1036.
The efficacy of trifloxysulfuron with and without surfactant was evaluated against balsam apple (*Momordica charantia*), cat's claw vine (*Macfadyena unguis-cati*), Florida beggar weed (*Desmodium tortuosum*), hairy beggar ticks (*Bidens pilosa*), ivyleaf morning glory (*Ipomoea hederacea* [*Pharbitis hederacea*]), Johnson grass (*Sorghum halapense*), prickly sida (*Sida spinosa*), redroot pigweed (*Amaranthus retroflexus*), sicklepod (*Senna obtusifolia*), strangler

vine (*Morrenia odorata*), tall morning glory (*I. purpurea* [*Pharbitis purpurea*]) and yellow nutsedge (*Cyperus esculentus*) at 21, 42 and 63 g/ha a.i applied at the 4- or 6-leaf stages and compared with glyphosate at 280, 560 and 840 g/ha a.i. Delayed application from the 4- to 6-leaf stage significantly reduced trifloxysulfuron efficacy; reduction was less with glyphosate. Trifloxysulfuron + 0.25% X-77 was more effective on the 4-leaf stage than on the 6-leaf stage plants of redroot pigweed, Johnson grass, hairy beggar ticks, strangler vine, and prickly sida; effect was similar on yellow nutsedge, sicklepod, Florida beggar weed, balsam apple, ivyleaf morning glory and tall morning glory. Trifloxysulfuron at 63 g/ha + surfactant reduced the fresh weight of all test plants more than 80% compared with the control, except for prickly sida, strangler vine, and cat's claw vine. Glyphosate was less effective than trifloxysulfuron + surfactant against tall morning glory, sicklepod, ivyleaf morning glory, and yellow nutsedge, but was significantly better against balsam apple, prickly sida and cat's claw vine. None of the herbicides provided satisfactory control of cat's claw vine, strangler vine and prickly sida.

Muehlenbeckia australis

81. Williams PH 1998. Control of Japanese honeysuckle. Wellington, Department of Conservation. http://www.doc.govt.nz/upload/documents/science-and-technical/sfc100.pdf

Three weeds of high conservation concern – Japanese honeysuckle (*Lonicera japonica*), climbing dock (*Rumex sagittatus*), and bone-seed (*Chrysanthemoides monilifera*) – were sprayed with a range of herbicides. The three weeds, and their associated native vegetation, were monitored to determine their response after control. Japanese honeysuckle was initially knocked back, but some plants showed signs of recovery from vegetative parts. No honeysuckle seedlings emerged, and native species recovered by vegetative means. Most of the dock was killed by the spraying, as well as a small proportion of the associated native vegetation. Sprayed dock plants failed to regenerate, but new plants emerged from seed. The native vegetation showed signs of recovery. The sprayed boneseed plants were killed, as were a few native plants that were inadvertently sprayed. However, by the spring following the spraying, boneseed seedlings were common. By the following winter, boneseed seedlings and small plants were abundant, many of them flowering. There was no similar flush of seedlings of native species.

Asparagus africanus

82. Armstrong TR, Breaden RC, et al. 2006. The control of climbing asparagus (*Asparagus africanus* Lam.) in remnant Brigalow scrub in south-east Queensland. Plant Protection Quarterly 21(3): 134–136.

A replicated trial was conducted in 2000 at Tallegalla in south-east Queensland, Australia, to assess the effectiveness of a range of control methods for climbing asparagus, *Asparagus africanus*. A total of 18 treatments using mechanical, cut stump, basal bark, foliar spray and splatter gun techniques were trialled with a range of herbicides (diesel, glyphosate, fluroxypyr ester, triclopyr ester and metusulfuron-methyl [metsulfuron]) and application rates. Removing the plant and placing it above the ground surface was the most effective in killing climbing asparagus. Basal bark spraying of 24 g triclopyr ester (40 ml Garlon 600) or 10 g fluroxypyr ester (50 ml Starane 200) l-1diesel and the cut stump application of neat diesel or 225 g glyphosate (500 ml Glyphosate CT) l-1 water offered the best chemical control of climbing asparagus.