

Copyright is owned by the Author of the thesis. Permission is given for a copy to be downloaded by an individual for the purpose of research and private study only. The thesis may not be reproduced elsewhere without the permission of the Author.

GROUND COVER PLANTS FOR WEED CONTROL IN AMENITY HORTICULTURE

A thesis presented in partial fulfilment of the
requirements for the degree of Doctor of Philosophy (PhD)
in Plant Science
at Massey University
Palmerston North, New Zealand



Chin Lui Foo
2012

Abstract

Aspects of the establishment and use of ground cover plants for urban weed control were investigated. Established ground cover populations of different taxa were monitored over 1 year at 14 sites for their ability to block light from the soil and prevent weeds from establishing. Field trials compared 12 ground cover species of widely differing growth form for rate of establishment and ability to block light and suppress weeds. Another field trial compared various types of mulch with selective herbicides and hand weeding as techniques for establishing ground cover species. No single growth form was superior to others, and it was the density of the foliage that was key to suppressing weeds. Ground cover plants should be selected for having persistently dense canopies throughout the year, such as *Coprosma acerosa* 'Taiko' and *Juniperus procumbens*. Deciduous species like *Persicaria capitata*, evergreen species which become sparser in winter like *Pimelea prostrata*, and plant canopies which open up during flowering like *Grevillea lanigera*, all allow weeds to germinate while the ground is exposed. Ground cover plants appear to deter weeds mainly by keeping weed seeds dormant through preventing red light from reaching weed seeds and triggering a phytochrome response leading to germination. Keeping the ratio of red to far-red light below 0.3 appeared to give best inhibition of weed seed germination. Presence of mulch and spot application of selective herbicides can help prevent weeds causing problems should gaps appear within ground covers, and these may be preferable to hand weeding. Little herbicide tolerance information exists for ornamental ground cover plants, so herbicide tolerance trials were conducted on eight ground cover plant species. This work showed that herbicides can aid in ground cover plant establishment and subsequent maintenance to selectively spot-treat weeds that appear. Ground cover species were assessed which grow low enough to be mowed but which seldom need mowing, to replace grass turf in situations where mowing is inconvenient such as under trees, on slopes, or roadsides. *Dichondra micrantha* and *Soleirolia soleirolii* showed the most potential, forming dense low growing swards that tolerated a wide range of herbicides.

Acknowledgements

I wish to express my sincere thanks and gratitude to my chief supervisor Dr Kerry Harrington for his patience and guidance throughout my period of candidature, for always making time available to discuss my research and providing insightful comments at every stage.

I am also grateful for Dr Marion Mackay who pointed me in the right direction on matters relating to taxonomy and amenity horticulture and for her encouragement.

Thanks are due to Nafees Anwar for providing statistical advice and guidance.

Thanks are also due to Messrs. Craig McGill and Robert Southward for their knowledge on seeds.

I would also like to thank Mr Martin Wrigley for his contributions and advice during the early phase of this project.

This work was also made possible through the technical assistance provided by the team led by Mr. Steven Ray at the Plant Growth Unit, especially to Lesley, Lindsay, and Scott; also to Mr Mark Osborne and his team; and plant science technicians Ms Kay Sinclair and Mr James Slater who assisted with my field work.

Financial assistance was rendered by the Massey University Doctoral Scholarship, the Dan Watkins Scholarship administered by the New Zealand Plant Protection Society, and the Sir Victor Davis Foundation.

Thanks are also due to the various herbicide companies for providing their products in trials, and to the EcoCover Company for providing the paper mulch used.

Dedications

This thesis is especially dedicated in loving memory of my father and grandmother, who were always a source of inspiration and encouragement.

I would also like to dedicate this work to everyone at home who provided emotional comfort and support during this long journey of scholarship.

Table of contents

Abstract.....	i
Acknowledgements.....	iii
Dedications	v
Table of contents	vii
List of Figures	xii
List of Tables	xiv
Chapter 1 Introduction.....	1
Chapter 2 Literature Review	5
2.0 Introduction	5
2.1 Use of ground cover plants and popularity of turf grass	5
2.2 Limitations of turf grass as ground cover	6
2.3 Benefits of ground cover plants in landscape and amenity horticulture	7
2.4 Competition by ground cover plants over weeds.....	11
2.5 Plant cover effects on seed germination	12
2.6 Importance of light for seed germination.....	13
2.7 Phytochrome action in seed germination.....	13
2.8 Emergence of ground cover plants for weed control in agriculture.....	17
2.9 Ground cover plant research in the urban environment.....	19
2.10 Production of ground cover plants	20
2.11 Establishment of ground cover plants	20
2.12 Mulches.....	22
2.12.1 Organic mulches.....	23
2.12.2 Inorganic mulches	26
2.13 Applications of ground cover plant in plant production.....	29
2.13.1 Considerations for ground cover plants in revegetation	29
2.13.2 Considerations for ground cover plants in agroforestry.....	30
2.13.3 Current use of ground cover plants in orchards and crop farms.....	30
2.13.4 Effects of ground cover plants on bare soil	32
2.14 Summary	33
Chapter 3 Assessing ground cover plants of various forms and growth habits.....	35
3.1 Review.....	35
3.2 Trial objectives	35

3.3 Materials: Species introduction	36
3.4 Methods.....	44
3.4.1 Methods: Establishment of 12 ground cover plant species	44
3.4.2 Methods: Rate of establishment -- Measuring diameter and height	45
3.4.3 Methods: Visual estimate of plot coverage of ground cover plants.....	46
3.4.4 Methods: Light quality under the ground cover foliage	46
3.4.5 Methods: Weed germination in plots with established ground cover plants	47
3.4.6 Methods: Data Analysis	48
3.5 Results.....	48
3.5.1 Results: Diameter of the plants	48
3.5.2 Results: Visual estimate of plot coverage of ground cover plants	50
3.5.3 Results: Height of the plants.....	52
3.5.4 Results: Visual estimate of canopy foliage density of ground cover plants	54
3.5.5 Results: Light quality under ground cover foliage	56
3.5.6 Results: Mean dry mass of weeds growing within each plot and under ground cover foliage.....	58
3.6 Discussion.....	60
Chapter 4 Comparing canopy covers of established ground cover species.....	65
4.1 Introduction	65
4.2 Objectives.....	65
4.3 Sites monitored and species introduction	65
4.4 Methods.....	70
4.5 Results.....	71
4.5.1 Result data by species over one year.....	71
4.5.1a Data from <i>Agapanthus x hybrid</i> population.....	71
4.5.1b Data from <i>Ajuga reptans</i> population	73
4.5.1c Data from <i>Coprosma</i> population.....	75
4.5.1d Data from <i>Cotyledon orbiculata</i> var <i>oblonga</i> population	77
4.5.1e Data from <i>Gazania rigens</i> hybrids population	79
4.5.1f Data from <i>Grevillea lanigera</i> population	81
4.5.1g Data from <i>Hebe chathamica</i> population.....	83
4.5.1h Data from <i>Hedera helix</i> population.....	85
4.5.1i Data from <i>Juniperus procumbens</i> in Palmerston North City.....	87
4.5.1j Data from <i>Juniperus chinensis</i> at Massey University	89

4.5.1k Data from <i>Muehlenbeckia axillaris</i> population	91
4.5.1l Data from <i>Pimelea prostrata</i> population	93
4.5.1m Data from <i>Plectranthus ciliatus</i> population	95
4.5.1n Data from <i>Viola sp.</i> population	97
4.5.2 Light quality data across all populations by quarterly interval.....	99
4.6 Discussion.....	101
4.7 Conclusion.....	107
Chapter 5 Herbicide trials for three ground cover species of different growth forms	109
5.1 Introduction	109
5.1.1 Objective	109
5.2 Herbicide trials	110
5.2.1 <i>Persicaria capitata</i> herbicide trials	111
5.2.1a <i>Persicaria capitata</i> herbicide trial: Materials and methods.....	111
5.2.1b <i>Persicaria capitata</i> herbicide trial: Results	112
5.2.1c <i>Persicaria capitata</i> herbicide trials: Discussion.....	115
5.2.2 <i>Sedum mexicanum</i> herbicide trials.....	115
5.2.2a <i>Sedum mexicanum</i> herbicide trials: Materials and methods.....	115
5.2.2b <i>Sedum mexicanum</i> herbicide trial: Results	117
5.2.2c <i>Sedum mexicanum</i> herbicide trials: Discussion.....	119
5.2.3 <i>Coprosma acerosa</i> ‘Taiko’ herbicide trials	120
5.2.3a <i>Coprosma acerosa</i> ‘Taiko’ herbicide trial 1: Materials and methods	120
5.2.3b <i>Coprosma acerosa</i> ‘Taiko’ herbicide trial: Results	120
5.2.3c <i>Coprosma acerosa</i> ‘Taiko’ herbicide trial: Discussion	123
5.3 Conclusion.....	123
Chapter 6 Comparison of establishment methods for ground cover plants of three different growth forms.....	125
6.1 Introduction	125
6.2 Objective	126
6.3. Mulch and cover materials	126
6.4. Methods: Establishment trial.....	126
6.5 Rates of growth.....	130
6.5.1 Results: Rates of growth -- <i>Coprosma acerosa</i> ‘Taiko’	131
6.5.2 Results: Rates of growth -- <i>Persicaria capitata</i>	132
6.5.3 Results: Rates of growth -- <i>Sedum mexicanum</i> ‘Acapulco Gold’	133

6.5.4 Discussion: Rates of growth in various treatments	134
6.6 Soil moisture and temperature.....	134
6.6.1 Results: Soil moisture and temperature	134
6.6.2 Discussion: Soil moisture and temperature.....	135
6.7 Assessment of weeds found in plots	136
6.7.1 Results: Mean weed numbers found in plots	136
6.7.2 Results: Standardised weed mass found in plots	137
6.7.3 Discussion: Assessment of weeds found in plots.....	139
6.8 Overall Discussion	141
6.9 Conclusion.....	143
Chapter 7 Herbicide trials for five ground cover species suitable for companion planting with turf grass.....	145
7.1 Introduction	145
7.1.1 Objective	145
7.1.2 Species introduction: <i>Dichondra micrantha</i>	145
7.1.3 Species introduction: <i>Hydrocotyle microphylla</i>	146
7.1.4 Species introduction: <i>Sagina procumbens</i>	146
7.1.5 Species introduction: <i>Soleirolia soleirolii</i>	147
7.1.6 Species introduction: <i>Veronica serpyllifolia</i>	147
7.2 <i>Dichondra micrantha</i> herbicide trials	147
7.2.1 General comments on herbicides used and application method.....	147
7.2.2 <i>Dichondra micrantha</i> trials: Methods.....	148
7.2.3 <i>Dichondra micrantha</i> trials: Results.....	150
7.2.4 <i>Dichondra micrantha</i> trials: Discussion	153
7.3 Hydrocotyle trials.....	155
7.3.1 Hydrocotyle microphylla trials: Methods	155
7.3.2 Hydrocotyle microphylla trials: Results	156
7.3.3 <i>Hydrocotyle microphylla</i> herbicide trials: Discussion	159
7.4 <i>Sagina procumbens</i> herbicide trial	159
7.4.1 <i>Sagina procumbens</i> herbicide trial: Methods.....	159
7.4.2 <i>Sagina procumbens</i> herbicide trial: Results.....	160
7.4.3 <i>Sagina procumbens</i> herbicide trial: Discussion	162
7.5 <i>Soleirolia soleirolii</i> herbicide trials	162
7.5.1 <i>Soleirolia soleirolii</i> herbicide trials: Methods.....	162

7.5.2 <i>Soleirolia soleirolii</i> herbicide trials: Results.....	163
7.5.3 Field observations of <i>Soleirolia soleirolii</i>	167
7.5.4 <i>Soleirolia soleirolii</i> trials: Discussion	167
7.6 <i>Veronica serpyllifolia</i> herbicide trials.....	168
7.6.1 <i>Veronica serpyllifolia</i> herbicide trials: Methods	168
7.6.2 <i>Veronica serpyllifolia</i> herbicide trials: Results	169
7.6.3 <i>Veronica serpyllifolia</i> trial: Discussion.....	172
7.7 Conclusion.....	172
Chapter 8 Field trials with turf-compatible ground cover species.....	173
8.1 Introduction	173
8.2 Establishment of initial ground cover plots at Fruit Crops Unit (FCU).....	173
8.2.1 Determining rate of growth by point analysis	175
8.2.2 Determining rate of growth by point analysis: Results and discussion	175
8.3 Herbicide trial 1 at FCU	176
8.3.1 Herbicide trial 1 at FCU: Materials and methods.....	176
8.3.2 Herbicide trial 1 at FCU: Results	177
8.3.3 Herbicide trial 1 at FCU: Discussion	182
8.4 Herbicide trial 2 at FCU	183
8.4.1 Herbicide trial 2 at FCU: Materials and Methods	183
8.4.2 Herbicide trial 2 at FCU: Results	184
8.4.3 Herbicide Trial 2 at FCU: Discussion.....	186
8.5 Ground cover trial under poplar trees.....	186
8.5.1 Ground cover trial under poplar trees: Materials and methods	186
8.5.2 Ground cover trial under poplar trees: Results	190
8.5.3 Ground cover trial under poplar trees: Discussion	194
8.6 Conclusion.....	196
Chapter 9 Conclusion	199
9.1 Project overview	199
9.2 Thesis findings.....	200
9.3 Promoting use of ground cover plants in landscape decision-making	204
9.4 Threat of species new to cultivation being invasive	205
References	209

List of Figures

Figure 2.1 Schematic showing conditions for the conversion of phytochrome isomers.....	13
Figure 3.1 The trial site at 2 weeks after planting (left); and 4 months after planting (right).....	36
Figure 3.2 <i>Acaena inermis</i> ‘Purpurea’, whole plant (left) foliage close-up (right).....	37
Figure 3.3 <i>Ajuga reptans</i> ‘Caitlin’s Giant’, whole plant (left) foliage close-up (right)	38
Figure 3.4 <i>Coprosma acerosa</i> ‘Taiko’, whole plant (left) foliage close-up (right).....	38
Figure 3.5 <i>Grevillea lanigera</i> ‘Little Drummer Boy’, whole plant (left) foliage close-up (right)	39
Figure 3.6 <i>Juniperus procumbens</i> ‘Nana’, whole plant (left) foliage close-up (right).....	39
Figure 3.7 <i>Lithodora diffusa</i> ‘Grace Ward’, whole plant (left) foliage close-up (right).....	40
Figure 3.8 <i>Muehlenbeckia axillaris</i> , whole plant (left) foliage close-up (right)	41
Figure 3.9 <i>Ophiopogon planiscapus</i> , whole plant (left) foliage close-up (right).....	41
Figure 3.10 <i>Persicaria capitata</i> , whole plant (left) foliage close-up (right)	42
Figure 3.11 <i>Pimelea prostrata</i> ‘Anatoki’, whole plant (left) foliage close-up (right).....	42
Figure 3.12 <i>Sedum mexicanum</i> ‘Acapulco Gold’, whole plant (left) foliage close-up (right).....	43
Figure 3.13 <i>Veronica peduncularis</i> ‘Oxford Blue’, whole plant (left) foliage close-up (right)	43
Figure 3.14: Planting layout of the 12 species in a randomised complete block design. Triangles at the top indicating planting position for the column	45
Figure 3.15 (left) Top view of <i>Sedum mexicanum</i> in vegetative state	63
Figure 3.16 (middle) Top view of <i>Sedum mexicanum</i> in flowering state.....	63
Figure 3.17 (right) Sample flowering stem on left side, placed next to sample vegetative stem on right side. Note the tighter whorled foliage on the vegetative stem on right side	63
Figures 4.1, 4.2, 4.3 (L-R) <i>Agapanthus x hybrid</i> ; <i>Cotyledon orbiculata</i> var <i>oblonga</i> ; <i>Coprosma kirkii</i> ..	67
Figures 4.4, 4.5, 4.6 (L-R) <i>Gazania rigens</i> hybrids; <i>Hebe chathamica</i> ; <i>Hedera helix</i>	68
Figures 4.7, 4.8, 4.9 (L-R) <i>Juniperus chinensis</i> ; <i>Plectranthus ciliatus</i> ; <i>Viola sororia</i>	70
Figure 4.10 Mean R:FR of <i>Agapanthus x hybrid</i> population over one year; with lines showing standard errors; and squares not on line representing conditions where weeds were found.....	73
Figure 4.11 Mean R:FR of <i>Ajuga reptans</i> population over one year; with lines showing standard errors; and squares not on line representing conditions where weeds were found.	74
Figure 4.12 Mean monthly red to far-red light ratio under <i>Coprosma kirkii</i> canopy, over full year of 2010.	76
Figure 4.13 Mean red to far-red light ratio under canopy; with lines showing standard errors, over full year of 2010.	78
Figure 4.14 Mean R:FR of <i>Gazania rigens</i> population over one year; with lines showing standard errors; and square symbols not on line representing conditions where weeds* were found.....	80
Figure 4.15 Mean R:FR of <i>Grevillea lanigera</i> population over one year; with lines showing standard errors; and square symbols not on line representing conditions where weeds were found.	82
Figure 4.16 Mean R:FR of <i>Hebe chathamica</i> population over one year; with bars showing standard errors; and square symbols not on line representing conditions where weed* was found.	84

Figure 4.17 Mean R:FR of <i>Hedera helix</i> population over one year; with bars showing standard errors; and square symbols not on line representing conditions where weeds* were found.	86
Figure 4.18 Mean R:FR of <i>Juniperus procumbens</i> population over one year; with bars showing standard errors.	88
Figure 4.19 Mean R:FR of <i>Juniperus chinensis</i> population at Massey University over one year; with bars showing standard errors; and square square symbols not on line representing conditions where weeds were found.	90
Figure 4.20 Mean R:FR of <i>Muehlenbeckia axillaris</i> population over one year; with bars showing standard errors.	92
Figure 4.21 Mean R:FR of <i>Pimelea prostrata</i> population over one year; with bars showing standard errors; and square symbols not on line representing conditions where weeds were found.	94
Figure 4.22 Mean R:FR of <i>Plectranthus ciliatus</i> population over one year; with bars showing standard errors; and square symbol not on line representing conditions where weed* was found.	96
Figure 4.23 Mean R:FR of <i>Viola sororia</i> population over one year; with bars showing standard errors; and square symbols not on line representing conditions where weeds were found.	98
Figure 5.1 Hand held pump sprayer similar to the one used for herbicide application in trials.....	111
Figure 5.2 Sample of scores in herbicide trial (from left): <i>P. capitata</i> plants with scores 1, 3, 6, 9 ...	112
Figure 5.3 Sample of scores in herbicide trial (from left): <i>S. mexicanum</i> plants with scores 1, 3, 6, 9	116
Figure 5.4 Sample of scores in herbicide trial (from left): <i>C. acerosa</i> plants with scores 1, 3, 6, 9.....	120
Figure 6.1 The establishment trial four months after setup.....	127
Figure 6.2 Plot layout of combinations of ground cover species and eight establishment treatments	128
Figure 7.1 (from left to right) <i>Dichondra micrantha</i> damage rating 1, 3, 6, 9.....	148
Figure 7.2 (from left to right) <i>Hydrocotyle microphylla</i> damage rating 1, 3, 6, 9.....	155
Figure 7.3 (from left to right) <i>Sagina procumbens</i> damage rating 1, 3, 6, 9	160
Figure 7.4 (from left to right) <i>Soleirolia soleirolii</i> damage rating 1, 3, 6, 9.....	163
Figure 7.5 (from left to right) <i>Veronica serpyllifolia</i> damage rating 1, 5, 9	168
Figure 8.1 Layout plan of planting plots at Massey University Fruit Crops Unit	174
Figure 8.2 Planting layout of ground cover plants under poplar trees.....	187
Figure 8.3 <i>Dichondra micrantha</i> under poplar tree, nine months after transplanting.	188

List of Tables

Table 3.1	Assessment of data set skewness to determine best transformation, if necessary, on plot coverage by ground cover plants prior to ANOVA.	46
Table 3.2	Mean diameter (cm) of ground cover plants at 2 weeks, 3 months, 5 months, 7 months and 9 months after planting (MAP). Column means sharing the same letter are not significantly different at $p>0.05$	49
Table 3.3	Mean diameter (cm) of ground cover plants at 11 months; 13 months; 18 months; and 24 months after planting (MAP). Column means sharing the same letter are not significantly different at $p>0.05$	49
Table 3.4	Plot coverage (%) by all ground cover plants within the plot at 3 months; 5 months; 7 months; 9 months; and 11 months after planting (MAP). Column means sharing the same letter are not significantly different at $p>0.05$	51
Table 3.5	Plot coverage (%) by all ground cover plants within the plot at 13 months; 18 months; and 24 months after planting (MAP). Column means sharing the same letter are not significantly different at $p>0.05$	51
Table 3.6	Mean height (cm) of ground cover plants at 3 months; 5 months; 7 months; and 9 months after planting (MAP). Column means sharing the same letter are not significantly different at $p>0.05$	52
Table 3.7	Mean height (cm) of ground cover plants at 11 months; 13 months; 18 months; and 24 months after planting (MAP). Column means sharing the same letter are not significantly different at $p>0.05$	53
Table 3.8	Mean estimated foliage density (%) of individual ground cover plants at 3 months; 5 months; 7 months; and 9 months after planting (MAP). Column means sharing the same letter are not significantly different at $p>0.05$	54
Table 3.9	Mean estimated foliage density (%) of individual ground cover plants at 11 months; 13 months; 18 months; and 24 months after planting (MAP). Column means sharing the same letter are not significantly different at $p>0.05$	55
Table 3.10	Mean reduction (%) of red, far-red and total light through foliage canopy in June 2010, and the mean ratio of red to far-red light (R:FR) . Column means sharing the same letter are not significantly different at $p>0.05$	56
Table 3.11	Mean reduction (%) of red, far-red and total light through foliage canopy in Nov 2010, and the mean ratio of red to far-red light (R:FR). Column means sharing the same letter are not significantly different at $p>0.05$	57
Table 3.12	Mean dry mass of weeds growing from 18 May – 2 Nov 2010 both within and out of ground cover canopy and mean R: FR in June and November, by species. Column means sharing the same letter are not significantly different at $p>0.05$	59
Table 3.13	Weeds found growing within the ground cover plant canopy in November 2010, with the most common listed first.	60
Table 3.14	Comparison between mean weed mass and recorded R:FR.	61
Table 4.1	Estimated ground coverage; plant height; mean visible light (400-700 nm) transmission; mean red light (660 nm) transmission; and mean far-red light (730 nm) transmission; in <i>Agapanthus x hybrid</i> over one year.	72

Table 4.2	Weeds found within <i>Agapanthus x hybrid</i> , in ascending order of R:FR value for the month listed.....	72
Table 4.3	Estimated ground coverage; plant height; mean visible light (400-700 nm) transmission; mean red light (660 nm) transmission; and mean far-red light (730 nm) transmission; in <i>Ajuga reptans</i> over one year.....	74
Table 4.4	Weeds found within <i>Ajuga reptans</i> , in ascending order of R:FR value for the month listed.....	75
Table 4.5	Estimated ground coverage; plant height; mean visible light (400-700 nm) transmission; mean red light (660 nm) transmission; and mean far-red light (730 nm) transmission; in <i>Coprosma kirkii</i> over one year.....	75
Table 4.6	Estimated ground coverage; plant height; mean visible light (400-700 nm) transmission; mean red light (660 nm) transmission; and mean far-red light (730 nm) transmission; in <i>Cotyledon orbiculata</i> var <i>oblonga</i> over one year.....	77
Table 4.7	Estimated ground coverage; plant height; mean visible light (400-700 nm) transmission; mean red light (660 nm) transmission; and mean far-red light (730 nm) transmission; in <i>Gazania rigens</i> hybrids over one year.....	79
Table 4.8	Estimated ground coverage; plant height; mean visible light (400-700 nm) transmission; mean red light (660 nm) transmission; and mean far-red light (730 nm) transmission; in <i>Grevillea lanigera</i> ‘Little Drummer Boy’ over one year.....	81
Table 4.9	Weeds found within <i>Grevillea lanigera</i> , in ascending order of R:FR value for the month listed.....	82
Table 4.10	Estimated ground coverage; plant height; mean visible light (400-700 nm) transmission; mean red light (660 nm) transmission; and mean far-red light (730 nm) transmission; in <i>Hebe chathamica</i> over one year.....	83
Table 4.11	Estimated ground coverage; plant height; mean visible light (400-700 nm) transmission; mean red light (660 nm) transmission; and mean far-red light (730 nm) transmission; in <i>Hedera helix</i> over one year.....	85
Table 4.12	Estimated ground coverage; plant height; mean visible light (400-700 nm) transmission; mean red light (660 nm) transmission; and mean far-red light (730 nm) transmission; in <i>Juniperus procumbens</i> over one year.....	87
Table 4.13	Estimated ground coverage; plant height; mean visible light (400-700 nm) transmission; mean red light (660 nm) transmission; and mean far-red light (730 nm) transmission; in <i>Juniperus chinensis</i> over one year.....	89
Table 4.14	Weeds found within <i>Juniperus chinensis</i> , in ascending order of R:FR value for the month listed.....	90
Table 4.15	Estimated ground coverage; plant height; mean visible light (400-700 nm) transmission; mean red light (660 nm) transmission; and mean far-red light (730 nm) transmission; in <i>Muehlenbeckia axillaris</i> over one year.....	91
Table 4.16	Estimated ground coverage; plant height; mean visible light (400-700 nm) transmission; mean red light (660 nm) transmission; and mean far-red light (730 nm) transmission; in <i>Pimelea prostrata</i> over one year.....	93
Table 4.17	List of weeds found within <i>Pimelea prostrata</i> , in ascending order of R:FR value for the month listed.....	94

Table 4.18	Estimated ground coverage; plant height; mean visible light (400-700 nm) transmission; mean red light (660 nm) transmission; and mean far-red light (730 nm) transmission; in <i>Plectranthus ciliatus</i> over one year.	95
Table 4.19	Estimated ground coverage; plant height; mean visible light (400-700 nm) transmission; mean red light (660 nm) transmission; and mean far-red light (730 nm) transmission; in <i>Viola sororia</i> over one year.	97
Table 4.20	Weeds found within <i>Viola sororia</i> , in ascending order of R:FR value for the month listed.....	98
Table 4.21	Mean visible Light transmission (% quality) in January, April, July and October 2010.....	99
Table 4.22	Mean red light (660 nm) transmission (% quality) in January, April, July and October 2010	100
Table 4.23	Mean far red light (730 nm) transmission (% quality) in January, April, July and October 2010	100
Table 4.24	Mean red to far red light ratios (R:FR) under the ground cover canopy in January, April, July and October 2010.....	101
Table 5.1	Product list and description of herbicides used in trials for Chapter 5	110
Table 5.2	Mean scores (1 = healthy, 10 = dead) of herbicide treatments on <i>Persicaria capitata</i> trial 1 at 1-18 weeks after treatment (WAT)	113
Table 5.3	Mean scores (1 = healthy, 10 = dead) of herbicide treatments on <i>Persicaria capitata</i> trial 2 at 3-21 weeks after treatment (WAT)	114
Table 5.4	Mean scores (1 = healthy, 10 = dead) of treatments on <i>S. mexicanum</i> Trial 1 at 1-18 weeks after treatment (WAT).....	117
Table 5.5	Mean scores (1 = healthy, 10 = dead) of herbicide treatments on <i>Sedum mexicanum</i> trial 2 at 3-20 weeks after treatment (WAT)	118
Table 5.6	Mean scores (1 = healthy, 10 = dead) of herbicide treatments on <i>Persicaria capitata</i> trial 1 at 3-15 weeks after treatment (WAT)	121
Table 5.7	Mean scores (1 = healthy, 10 = dead) of herbicide treatments on <i>Coprosma acerosa</i> trial 1 at 2-20 weeks after treatment (WAT)	122
Table 6.1	Herbicides applied for herbicide treatment plots	129
Table 6.2	The change in mean plant diameter of <i>Coprosma acerosa</i> cv Taiko for different establishment techniques. Column means sharing the same letter are not significantly different at $p>0.05$	131
Table 6.3	The change in mean plant height of <i>Coprosma acerosa</i> cv Taiko for different establishment techniques. Column means sharing the same letter are not significantly different at $p>0.05$	131
Table 6.4	The change in mean estimated ground coverage (%) of <i>Coprosma acerosa</i> cv Taiko for different establishment techniques. Column means sharing the same letter are not significantly different at $p>0.05$	131
Table 6.5	The change in mean plant diameter of <i>Persicaria capitata</i> for different establishment techniques. Column means sharing the same letter are not significantly different at $p>0.05$	132
Table 6.6	The change in mean plant height of <i>Persicaria capitata</i> for different establishment techniques. Column means sharing the same letter are not significantly different at $p>0.05$	132

Table 6.7	The change in mean estimated ground coverage (%) of <i>Persicaria capitata</i> for different establishment techniques. Column means sharing the same letter are not significantly different at $p>0.05$	133
Table 6.8	The change in mean plant diameter of <i>Sedum mexicanum</i> cv Acapulco Gold for different establishment techniques. Column means sharing the same letter are not significantly different at $p>0.05$	133
Table 6.9	The change in mean plant height of <i>Sedum mexicanum</i> cv Acapulco Gold for different establishment techniques. Column means sharing the same letter are not significantly different at $p>0.05$	133
Table 6.10	The change in mean estimated ground coverage (%) of <i>Sedum mexicanum</i> cv Acapulco Gold for different establishment techniques. Column means sharing the same letter are not significantly different at $p>0.05$	134
Table 6.11	Soil moisture content sampled over two summers and the mean maximum and minimum temperatures in summer and winter of soil under various treatments. Column means sharing the same letter are not significantly different at $p>0.05$	135
Table 6.12	Mean weed numbers per plot found within <i>Coprosma acerosa</i> cv Taiko plot boundaries that had established since removal following the previous assessment. Column means sharing the same letter are not significantly different at $p>0.05$	136
Table 6.13	Mean weed numbers per plot found within <i>Persicaria capitata</i> plot boundaries, built up after weed removal from previous observations. Column means sharing the same letter are not significantly different at $p>0.05$	136
Table 6.14	Mean weed numbers per plot found within <i>Sedum mexicanum</i> cv Acapulco Gold plot boundaries, built up after weed removal from previous observations. Column means sharing the same letter are not significantly different at $p>0.05$	137
Table 6.15	Dry weed mass (g m^{-2}) of each treatment plot by species, with differentiation between weeds found within and beyond the ground cover canopy. Column means sharing the same letter are not significantly different at $p>0.05$	138
Table 6.16	Weeds found in the establishment trial plots	138
Table 7.1	Product list and description of herbicides used in trials reported within this chapter.	149
Table 7.2	Mean scores of plant damage (1 = healthy, 10 = dead) for the first herbicide screening of <i>Dichondra micrantha</i> 1-18 weeks after treatment (WAT).	151
Table 7.3	Mean scores of plant damage (1 = healthy, 10 = dead) for the second herbicide screening of <i>Dichondra micrantha</i> 3-20 weeks after treatment (WAT).	152
Table 7.4	Mean scores of plant damage (1 = healthy, 10 = dead) for the first herbicide screening of <i>Hydrocotyle microphylla</i> 1-18 weeks after treatment (WAT).	156
Table 7.5	Mean scores of plant damage (1 = healthy, 10 = dead) for the second herbicide screening of <i>Hydrocotyle microphylla</i> 3-11 weeks after treatment (WAT).	157
Table 7.6	Mean scores of plant damage (1 = healthy, 10 = dead) for the third herbicide screening of <i>Hydrocotyle microphylla</i> 1-7 weeks after treatment (WAT).	158
Table 7.7	Mean scores of plant damage (1 = healthy, 10 = dead) for the herbicide screening of <i>Sagina procumbens</i> 1-9 weeks after treatment (WAT).	161
Table 7.8	Mean scores of plant damage (1 = healthy, 10 = dead) for the first herbicide screening of <i>Soleirolia soleirolii</i> 3-19 weeks after treatment (WAT).	164
Table 7.9	Mean scores of plant damage (1 = healthy, 10 = dead) for the second herbicide screening of <i>Soleirolia soleirolii</i> 1-17 weeks after treatment (WAT).	166

Table 7.10 Mean scores of plant damage (1 = healthy, 10 = dead) for the first herbicide screening of <i>Veronica serpyllifolia</i> 1-18 weeks after treatment (WAT).....	169
Table 7.11 Mean scores of plant damage (1 = healthy, 10 = dead) for the second herbicide screening of <i>Veronica serpyllifolia</i> 3-21 weeks after treatment (WAT).....	170
Table 7.12 Mean scores of plant damage (1 = healthy, 10 = dead) for the third herbicide screening of <i>Veronica serpyllifolia</i> 3-19 weeks after treatment (WAT).....	171
Table 8.1 Mean plot coverage by ground cover species 1- and 9-months after planting.....	175
Table 8.2 Herbicide damage scores of <i>Dichondra micrantha</i> plants and main weeds present in plots at various days after treatment (DAT), with overall weed mortality after 40 days.	178
Table 8.3 Herbicide damage scores of <i>Hydrocotyle microphylla</i> plants and main weeds present in plots at various days after treatment (DAT), with overall weed mortality after 40 days.	179
Table 8.4 Herbicide damage scores of <i>Sedum mexicanum</i> plants and main weeds present in plots at various days after treatment (DAT), with overall weed mortality after 40 days.	180
Table 8.5 Herbicide damage scores of <i>Sagina procumbens</i> plants and main weeds present in plots at various days after treatment (DAT), with overall weed mortality after 40 days.	181
Table 8.6 Herbicide damage scores of <i>D. micrantha</i> plants at various days after treatment (DAT)	184
Table 8.7 Herbicide damage scores of <i>H. microphylla</i> plants at various days after treatment (DAT)	184
Table 8.8 Herbicide damage scores of <i>S. procumbens</i> plants at various days after treatment (DAT)	185
Table 8.9 Herbicide damage scores of <i>S. mexicanum</i> plants at various days after treatment (DAT)	185
Table 8.10 Herbicide damage scores of <i>V. serpyllifolia</i> plants at various days after treatment (DAT)	185
Table 8.11 Herbicides for broad-leaved weeds used during establishment of ground cover plants under poplar trees.	189
Table 8.12 Percentage (%) of ground cover plots under poplar trees occupied by ground cover species, the perennial weed <i>Ranunculus repens</i> , other weeds and bare soil in March and April 2010. Column means sharing the same letter are not significantly different at $p>0.05$	190
Table 8.13 Percentage (%) of ground cover plots under poplar trees occupied by ground cover species, the perennial weed <i>Ranunculus repens</i> , other weeds and bare soil in May, June, August, and October 2010. Column means sharing the same letter are not significantly different at $p>0.05$	191
Table 8.14 Percentage (%) of ground cover plots under poplar trees occupied by ground cover species, the perennial weed <i>Ranunculus repens</i> , other weeds and bare soil in May, June, August, and October 2010. Column means sharing the same letter are not significantly different at $p>0.05$	192
Table 8.15 Weeds found under poplar trees in April and May 2010.	193