

# Canopy management strategies for macadamia

(*Macadamia integrifolia*, *M. integrifolia* × *M. tetraphylla*).



Lisa Maree McFadyen

Bachelor of Science in Agriculture, The University of Sydney

Master of Science, Macquarie University

*A thesis submitted for the degree of Doctor of Philosophy of the University of New*

*England*

*November 2012*

## Acknowledgements

The work was funded by Horticulture Australia Limited using the macadamia industry levy and matched funds from the Federal Government. In-kind support was provided by my employer, NSW Department of Primary Industries.

I thank my supervisors, Dr Trevor Olesen, Professor Margaret Sedgley and Dr Paul Kristiansen for their interest, guidance and generous encouragement and support during this study.

I am grateful to David Robertson for his exceptional technical assistance and helpful suggestions and discussion. His thoughtful, precise and tireless work was crucial to this study.

I also thank other staff from NSW Department of Primary Industries: Russell Priddle, Margaret Oldham, Glenn Smith, Steven Muldoon, Alister Janetski, Magda Verbeek, Robyn Andrews and Lloyd Morgan for technical support; David Meyer, Glenn Smith and Steven Muldoon for carbohydrate analyses; Geoff Quinn, Matthew Stewart, Mick Bolt and Graeme Laing for maintaining trees used in experiments at the Centre for Tropical Horticulture at Alstonville; Stephen Morris for assistance with and advice on statistical analyses and ‘R’ programming; Jennifer Kirton for library support; Stephen Morris, Don Irving and Shane Hetherington for comments on parts of the thesis; and Jenny McInnes for assistance with formatting.

I am grateful to the following growers for allowing access to their orchards to conduct experiments and for their assistance and cooperation: Sherie Ainsbury, Nick App App, Surrey Bogg, Lindsay Bryen, Ken Haselden, Ian Hotson, Cliff and Greg James, Ian Mulligan, David Rodgers, Mike Thomas, John Townsend and Terry

Walker. I also thank Sumitomo Chemicals Australia Pty Ltd for donating the plant growth regulator Retain®.

I dedicate this thesis to my husband, Tim, and our children, Sean and Anna, for their love, patience, understanding and support.

## Abstract

Macadamia is a subtropical evergreen tree native to the east coast of Australia and grown around the world for its edible kernel. The trees are tall with dense canopies and at maturity orchards are heavily shaded and crowded unless tree size is controlled. This shading has been associated with yield decline but the evidence for this is limited to one site. The shading also limits ground-cover growth leading to increased soil erosion; slows orchard floor drying after rain resulting in harvest delays and reduced nut quality; and increases pest and disease pressure. Crowded orchards are also more difficult to spray effectively.

The aims of this study were to further investigate the evidence for yield decline, assess canopy management methods adopted by industry, and investigate the effect of pruning on fruit set to improve outcomes from some of these methods.

A yield survey in mature orchards confirmed earlier conclusions that yield decline occurred at high levels of light interception but that it was small compared with inter-seasonal yield variation.

Selective limb removal increased yield in one trial, decreased it in another and did not have a lasting effect of increasing light transmission to the orchard floor for ground growth or orchard floor drying. Side-hedging maintained light to the inter-row, but reduced yield by 12% on average over 7 seasons. Hedging the tops of trees (topping) was a more practical method of tree size control than selective removal of limbs at the top of the canopy but it reduced yield by up to 50%.

The standard hedging time in the Australian industry is early spring (September) around flowering and early fruit development. Subsequent experiments

demonstrated that hedging at this time decreased yield by accentuating early fruit abscission. The primary cause appeared to be competition for carbohydrates between the post-hedging shoot growth and the young fruit, with a secondary effect due to the loss of photosynthetic canopy. The effect was local with shoot growth on pruned branches having no effect on unpruned branches.

A series of experiments tested the hypothesis that fruit are less sensitive to a limitation in carbohydrate supply outside the premature fruit drop period, and that pruning at a time that avoided shoot growth during this period may mitigate the yield penalty. Hedging time was found to affect yields of the four cultivars tested: ‘A4’, ‘A38’, ‘344’ and ‘816’. Yield losses were lower for trees hedged in November–December than for trees hedged in September. Yields for trees hedged in June were higher than September-hedged trees in one experiment but were similar in another experiment. Yield losses for September- and October-hedged trees were similar. Declines in stem water-soluble carbohydrates occurred after hedging in September, October and November, and preceded an increase in fruit abscission. However, the increase was less pronounced for November-pruned trees, consistent with the idea that fruit become less sensitive to carbon limitation as they mature.

Two other strategies to mitigate the effect of hedging on fruit abscission and yield were investigated. The first of these, the ethylene inhibitor aminoethoxyvinylglycine was applied at a range of combinations up to 600 mg L<sup>-1</sup> and at two times but it did not increase final fruit set or yield in pruned or unpruned trees. Further work with timing of application may improve outcomes or it may be that ethylene is not the main control of fruit abscission in macadamia. The second strategy, girdling, reduced the negative effect of pruning on fruit abscission, but

girdling was not as effective as varying the time of hedging in mitigating the effect of hedging on yield.

Girdling also reduced shoot growth in pruned and unpruned trees and may have potential as a tree size control strategy for macadamia. Girdling trees in three out of four seasons reduced the tree height increment to half that of ungirdled trees. Average yield for this period was similar for girdled and ungirdled trees, but further monitoring is required to determine long-term yield effects.

## Table of contents

<b>Acknowledgements .....</b>	<b>i</b>
<b>Abstract.....</b>	<b>iii</b>
<b>Declaration.....</b>	<b>vi</b>
<b>Table of contents .....</b>	<b>vii</b>
<b>Chapter 1 .....</b>	<b>1</b>
<b>Introduction.....</b>	<b>1</b>
1.1    Botany of the macadamia.....	1
1.2    Cultivation.....	2
1.3    Approaches to canopy management research .....	4
1.4    Thesis structure .....	5
<b>Chapter 2 .....</b>	<b>8</b>
<b>Production trends in mature macadamia orchards and the effects of selective limb removal, side-hedging and topping on yield, nut characteristics, tree size and economics.....</b>	<b>8</b>
2.1    Abstract .....	8
2.2    Introduction.....	9
2.3    Materials and methods .....	12
2.3.1    Experiment 1: yield survey. ....	12
2.3.2    Experiment 2: the effects of selective limb removal and side-hedging on 16-year-old '246' trees.....	13
2.3.3    Experiment 3: the effect of topping on 10-year-old '344' trees.....	15
2.3.4    Experiment 4: the effects of topping and selective limb removal on 14- year-old '344' trees.....	16

2.3.5	Statistical analyses.....	17
2.4	Results.....	18
2.4.1	Experiment 1: yield survey.....	18
2.4.2	Experiment 2: the effects of selective limb removal and side-hedging on 16-year-old '246' trees.....	18
2.4.3	Experiment 3: the effect of topping on 10-year-old '344' trees.....	23
2.4.4	Experiment 4: the effects of topping and selective limb removal on 14- year-old '344' trees.....	24
2.5	Discussion .....	29
<b>Chapter 3</b>	<b>Post-pruning shoot growth increases fruit abscission and reduces stem carbohydrates and yield in macadamia .....</b>	<b>37</b>
<b>3.1</b>	<b>Abstract .....</b>	<b>37</b>
3.2	Introduction.....	38
3.3	Materials and methods .....	42
3.3.1	Macadamia .....	42
3.3.2	Experiment 1: tip-pruning all branches, and suppressing regrowth.....	43
3.3.3	Experiment 2: tip-pruning upper branches, and suppressing regrowth ....	44
3.3.4	Statistical analyses .....	45
3.4	Results.....	46
3.4.1	Experiment 1: tip-pruning all branches, and suppressing regrowth.....	46
3.4.2	Experiment 2: tip-pruning upper branches, and suppressing regrowth.....	54
3.5	Discussion .....	58
3.5.1	Experiment 1: tip-pruning all branches, and suppressing regrowth.....	58
3.5.2	Experiment 2: tip-pruning upper branches and suppressing regrowth.....	61

3.5.3	Conclusions .....	63
<b>Chapter 4 .....</b>	<b>64</b>	
<b>Time of pruning affects fruit abscission, stem carbohydrates and yield of macadamia.....</b>		<b>64</b>
4.1	Abstract .....	64
4.2	Introduction .....	64
4.3	Materials and methods .....	67
4.3.1	Experiment 1: the effects of September, October and December pruning on fruit per raceme, yield and shoot growth in cultivars ‘344’ and ‘A4’ ..	67
4.3.2	Experiment 2: the effects of June and September pruning on flowering, fruit abscission, yield and shoot growth in cultivars ‘816’ and ‘A38’ .....	69
4.3.3	Experiment 3: the effects of June, September, October and November pruning on flowering, fruit per raceme, yield, shoot growth and stem carbohydrates in cultivar ‘A4’ .....	71
4.3.4	Statistical analyses .....	73
4.4	Results.....	73
4.4.1	Experiment 1: the effects of September, October and December pruning on fruit per raceme, yield, and shoot growth in cultivars ‘344’ and ‘A4’ .	73
4.4.2	Experiment 2: the effects of June and September pruning on flowering, fruit abscission, yield, and shoot growth in cultivars ‘816’ and ‘A38’ .....	75
4.4.3	Experiment 3: the effects of June, September, October and November pruning on flowering, fruit per raceme, yield, shoot growth and stem carbohydrates in cultivar ‘A4’ .....	79
4.5	Discussion .....	88

4.5.1	Effects of hedging time on fruit abscission, yield, flowering and stem carbohydrates .....	88
4.5.2	Varietal effects .....	93
4.5.3	Seasonal variation in WSC and further interactions with pruning treatments .....	94
4.5.4	Effects of hedging time on post-pruning shoot production.....	96
4.5.5	Conclusions .....	97
<b>Chapter 5 .....</b>	<b>99</b>	
<b>Effects of the ethylene inhibitor aminoethoxyvinylglycine (AVG) on fruit abscission and yield on pruned and unpruned macadamia trees.....</b>		<b>99</b>
5.1	Abstract .....	99
5.2	Introduction.....	100
5.3	Materials and Methods.....	104
5.3.1	General .....	104
5.3.2	Experiment 1: AVG (0, 30, 60, 90 mg L <sup>-1</sup> ) applied to racemes on ‘849’ trees pre or post anthesis, 2007 .....	104
5.3.3	Experiment 2: two applications (pre and post anthesis) of AVG (0, 60 mg L <sup>-1</sup> ) applied to pruned and unpruned ‘A4’ trees, 2007 .....	105
5.3.4	Experiment 3: AVG (0, 200, 400, 600 mg L <sup>-1</sup> ) applied to racemes on ‘849’ trees pre or post anthesis, 2008 .....	106
5.3.5	Experiment 4: two applications (pre and post anthesis) of AVG (0, 400 mg L <sup>-1</sup> ) applied to pruned and unpruned ‘849’ trees, 2008.....	106
5.3.6	Statistical analyses .....	107
5.4	Results.....	107

5.4.1	Experiment 1: AVG (0, 30, 60, 90 mg L <sup>-1</sup> ) applied to racemes on ‘849’ trees pre or post anthesis, 2007 .....	107
5.4.2	Experiment 2: two applications (pre and post anthesis) of AVG (0, 60 mg L <sup>-1</sup> ) applied to pruned and unpruned ‘A4’ trees, 2007.....	109
5.4.3	Experiment 3: AVG (0, 200, 400, 600 mg L <sup>-1</sup> ) applied to racemes on ‘849’ trees pre or post anthesis, 2008 .....	109
5.4.4	Experiment 4: two applications (pre and post anthesis) of AVG (0, 400 mg L <sup>-1</sup> ) applied to pruned and unpruned ‘849’ trees, 2008.....	113
5.5	Discussion .....	113
5.5.1	Conclusions .....	116
<b>Chapter 6</b>	<b>Effects of girdling on fruit abscission, yield and shoot growth in macadamia...</b>	<b>117</b>
6.1	Abstract .....	117
6.2	Introduction .....	118
6.3	Materials and methods .....	119
6.3.1	Experiment 1: girdling and pruning trees at anthesis in early spring, 2008..	120
6.3.2	Experiment 2: girdling and pruning trees in autumn, 2009. ....	121
6.3.3	Experiment 3: girdling trees at anthesis in early spring, 2008 and 2009.121	
6.3.4	Statistical analyses .....	122
6.4	Results.....	122
6.4.1	Experiment 1: girdling and pruning trees at anthesis in early spring, 2008..	122
6.4.2	Experiment 2: girdling and pruning trees in autumn, 2009. ....	123
6.4.3	Experiment 3: girdling trees at anthesis in early spring, 2008 and 2009.123	

6.5	Discussion .....	131
<b>Chapter 7</b>	.....	<b>136</b>
<b>General Discussion</b>	.....	<b>136</b>
7.1	Future Directions .....	143
<b>References</b>	.....	<b>148</b>
<b>Publications and presentations</b>	.....	<b>174</b>
Scientific Journals.....	174	
Technical Reports .....	174	
Presentations .....	175	
Posters .....	176	