

**EFFECT OF CLIMATE AND CULTURAL PRACTICES ON
GRAPEVINE FLOWERING AND YIELD COMPONENTS**

Suzanne Jean McLoughlin

School of Agriculture, Food and Wine

Faculty of Sciences

The University of Adelaide

February 2009

A thesis submitted to the University of Adelaide in fulfilment of the
requirement for the degree of Master of Agricultural Science

TABLE OF CONTENTS

LIST OF TABLES.....	vi
LIST OF FIGURES.....	viii
ABSTRACT.....	ix
DECLARATION.....	xii
ACKNOWLEDGEMENTS.....	xiii
<u>CHAPTER ONE: General Introduction</u>	1
<u>CHAPTER TWO: Review of Literature</u>	
2.1. Introduction.....	5
2.2. The Grapevines as a horticultural crop.....	5
2.3. Grapevine phenology.....	5
2.3.1 Budburst.....	6
2.3.2 Shoot and inflorescence development following budburst.....	7
2.3.3 Flowering, fertilisation and fruit set.....	9
2.4. Grapevine reproductive phase.....	11
2.4.1 Node Fertility and Inflorescence development.....	13
2.4.2 Flower development.....	15
2.5. Environmental factors influencing inflorescence and flower development.....	16
2.5.1 Temperature.....	16
2.5.2 Light.....	18
2.5.3 Water stress.....	19
2.6. Cultural factors influencing inflorescence and flower development	
2.6.1 Canopy management.....	20
2.6.2 Vine response to pruning system.....	22
2.7. Conclusion.....	23

CHAPTER THREE: Analysis of yield component variation from different bearer node numbers in a mechanically pruned system

3.0 Introduction.....	24
3.1 Materials and Methods	
3.1.1 Experimental site.....	26
3.1.2 Experimental Design.....	26
3.1.3 Vine Measurements.....	27
3.1.4 Statistical Analysis	29
3.2 Results	
3.2.1 Impact of bearer node number on vegetative and yield components	
3.2.1.1 Bearer node numbers retained after pruning.....	30
3.2.1.2 Trends in measured yield components from the proximal to the distal node positions on the bearers.....	32
3.2.1.3 Effect of node position on fruit set.....	38
3.2.1.4 Effect of node position on weight per flower and weight per berry.....	39
3.2.1.5 Relationships between yield and node position and yield and bearer node number and the change in the proportion of fruitful, non-fruitful and blind nodes on different bearer node numbers.....	40
3.2.2 Size difference of single as opposed to multiple inflorescences on a shoot	43
3.2.3 Relationship between the size of the inflorescence and the node position on the shoot at which it is located.....	45
3.3 Discussion	
3.3.1 Impact of bearer node number on vegetative and yield components	
3.3.1.1 Bearer node numbers retained after pruning.....	51
3.3.1.2 Trends in measured yield components from the proximal to the distal node positions on the bearers.....	52
3.3.1.3 Comparison of yield components at a terminal node position on a bearer compared with the same non-terminal node position on a longer bearer.....	54
3.3.1.4 Effect of node position on fruit set.....	55
3.3.1.5 Effect of node position on weight per flower and weight per berry.....	56

3.3.1.6 Relationships between yield and node position and yield and bearer node number and the change in the proportion of fruitful, non-fruitful and blind nodes on different bearer node numbers.....	58
3.3.2 Size differences of single as opposed to multiple inflorescences on a shoot	59
3.3.3 Relationship between the size of the inflorescence and the node position on the shoot at which it is located.....	60
3.4 Conclusions.....	61

CHAPTER FOUR: Co-development of bunch number and bunch size

4.0 Introduction.....	63
4.1 Materials and Methods	
4.1.1 Experimental site.....	64
4.1.2 Experimental Design.....	65
4.1.3 Vine Measurements.....	65
4.1.4 Climatic data.....	66
4.1.5 Statistical Analyses.....	66
4.2 Results	
4.2.1 Fertility	
4.2.1.1 Effect of variety on fertility (bunches per node) and yield components.....	67
4.2.1.2 Effect of growing season and temperature on fertility (bunches per node) and yield components.....	68
4.2.1.3 Effect of variety and growing season on fertility (bunches per node) and yield components.....	69
4.2.1.4 Effect of vineyard site and variety on fertility (bunches per node) and yield components.....	69
4.2.2 Fruit set	
4.2.2.1 Effect of vineyard site and variety on flower number per inflorescence, berry number per bunch and fruit set.....	74
4.2.2.2 Effect of season on flower number per inflorescence, berry number per bunch and fruit set.....	74
4.2.3 Variation in Yield.....	76
4.3 Discussion	

4.3.1 Fertility	
4.3.1.1 Correlations between fertility (bunches per node) and yield components.....	80
4.3.1.2 Effect of growing season on yield components.....	80
4.3.1.3 Effect of variety and vineyard site on fertility (bunches per node).....	81
4.3.1.4 Effect of vineyard site on fertility (bunches per node) and yield components.....	82
4.3.1.5 Effect of vineyard site and variety on bunch weight.....	82
4.3.2 Fruit set	
4.3.2.1 Effect of fertility (bunches per node) on flower number per inflorescence.....	83
4.3.2.2 Effect of flower number per inflorescence on fruit set.....	84
4.3.2.3 Effect of vineyard on flower number per inflorescence.....	85
4.3.3 Variation in Yield	
4.3.3.1 Crop Forecasting System.....	86
4.3.3.2 Fractions of seasonal variation in yield accounted for by seasonal variation in yield components.....	87
4.3.3.3 Effect of variety and 'pruning to fertility' on fractions of seasonal variation in yield accounted for by seasonal variation in yield components.....	87
4.3.3.4 Effect of vineyard site on fractions of seasonal variation in yield accounted for by the seasonal variation in yield components..	88
4.3.3.5 Effect of growing season on fractions of seasonal variation in yield accounted for by seasonal variation in yield components....	89
4.3.3.6 Future yield component data collection from the crop forecasting system.....	90
4.4 Conclusions.....	91
<u>CHAPTER FIVE: General Conclusions</u>	93
APPENDICES.....	101
REFERENCES.....	102

LIST OF TABLES

TABLE	PAGE
3.1. The effect of bearer cross-sectional area on the proportion of buds bursting on bearer lengths between 1 and 5 nodes for hedge pruned <i>Vitis vinifera</i> cv. Cabernet Sauvignon vines at Coonawarra (2005).....	31
3.2. Matrix of correlation coefficients determined for linear correlations from the treatment means of the measured variables for hedge pruned <i>Vitis vinifera</i> cv. Cabernet Sauvignon vines at Coonawarra (2005).....	37
3.3. The influence of inflorescence node position on yield components for hedge pruned <i>Vitis vinifera</i> cv. Cabernet Sauvignon vines at Coonawarra (2005).....	44
3.4. The influence of bunch node position on yield components for hedge pruned <i>Vitis vinifera</i> cv. Cabernet Sauvignon vines at Coonawarra (2005).....	45
3.5. The influence of node position on the shoot at which an inflorescence is located, on its pre-flowering yield components for hedge pruned <i>Vitis vinifera</i> cv. Cabernet Sauvignon vines at Coonawarra (2005).....	48
3.6. Comparison of pre-flowering yield components, for single inflorescences at different node positions counted from the base of the shoot, on shoots arising from different node positions from the base of the bearer for hedge pruned <i>Vitis vinifera</i> cv. Cabernet Sauvignon vines at Coonawarra (2005).....	49
3.7. Comparison of pre-flowering yield components, for both basal and apical inflorescences that occur at different node positions on the shoot, and occur on shoots at different node positions on the bearer for hedge pruned <i>Vitis vinifera</i> cv. Cabernet Sauvignon vines at Coonawarra (2005).....	50
4.1. Correlation between the variables fertility and bunch weight, flower number per inflorescence and berry number per bunch.....	67
4.2. Effect of variety on fertility and yield components.....	68
4.3. Effect of growing season on fertility and yield components.....	68
4.4. Heat summation during inflorescence primordium initiation and differentiation periods at Coonawarra, Robe and Padthaway for seasons 2002/03 to 2006/07.....	69
4.5. Effect of variety and season on fertility and yield components.....	71
4.6. Effect of vineyard site and variety on fertility and yield components.....	72

4.7. Correlation between the variables inflorescence initiation and differentiation temperatures on fertility and flower number per inflorescence for Cabernet Sauvignon	73
4.8. Correlation between the variables flower number per inflorescence and berry number per bunch.....	75
4.9. Mean daily temperature over the fruit set period at Coonawarra, Robe, Padthaway and Bordertown for years 2002 to 2007.....	76
4.10 Fractions of seasonal variation in weight per vine accounted for by the seasonal variation in bunches per vine, berries per bunch and weight per berry from 2003 – 2007 for <i>Vitis vinifera</i> cv. Chardonnay, Shiraz and Cabernet Sauvignon at Robe, Coonawarra and Padthaway.....	77
4.11 Fractions of seasonal variation in weight per vine accounted for by the seasonal variation in bunches per vine, berries per bunch and weight per berry by growing season for <i>Vitis vinifera</i> cv. Chardonnay, Shiraz and Cabernet Sauvignon at Robe, Coonawarra and Padthaway.....	78
4.12 Flower number per inflorescence, berry number per bunch and percentage fruit set by season from 2003/04 to 2006/07.....	79

LIST OF FIGURES

FIGURE	PAGE
2.1. The modified E-L system from Coombe (1995).....	6
2.2. Transverse section through a compound bud of a grapevine, showing relative positions of the leaf scar (LS), lateral shoot scar (LAT), primary bud (1) and the accessory buds (2) and (3). Adapted from Pratt, 1974.....	8
2.3. The Grapevine Reproductive Phase (adapted from Wilson, 1996).....	12
3.1 Frequency distribution of nodes per bearer after hedge pruning <i>Vitis vinifera</i> cv. Cabernet Sauvignon vines at Coonawarra (2005).....	30
3.2 Average cross-sectional area of bearer lengths between 1 and 5 nodes for hedge pruned <i>Vitis vinifera</i> cv. Cabernet Sauvignon vines at Coonawarra (2005).	31
3.3 Diagram of grapevine indicating bearer (brown) and node positions on bearer (a-f) and shoot (green) and node positions on shoot (i-vi).....	33
3.4 Percentage budburst at each node position for the bearer lengths between 1 and 5 nodes for hedge pruned <i>Vitis vinifera</i> cv. Cabernet Sauvignon vines at Coonawarra (2005).....	33
3.5 Percentage shoot fruitfulness at each node position for the bearer lengths between 1 and 5 nodes for hedge pruned <i>Vitis vinifera</i> cv. Cabernet Sauvignon vines at Coonawarra (2005).....	34
3.6 Average inflorescence number per burst node at each node position pre-flowering for the bearer lengths between 1 and 5 nodes for hedge pruned <i>Vitis vinifera</i> cv. Cabernet Sauvignon vines at Coonawarra (2005).....	35
3.7 Average flower number per inflorescence at each node position pre-flowering for the bearer lengths between 1 and 5 nodes for hedge pruned <i>Vitis vinifera</i> cv. Cabernet Sauvignon vines at Coonawarra (2005).....	36
3.8 Average berry number per bunch at each node position for the bearer lengths between 1 and 5 nodes for hedge pruned <i>Vitis vinifera</i> cv. Cabernet Sauvignon vines at Coonawarra (2005).....	37
3.9 Calculated percentage fruit set at each node position for the bearer lengths between 1 and 5 nodes for hedge pruned <i>Vitis vinifera</i> cv. Cabernet Sauvignon vines at Coonawarra (2005).....	38

3.10 Average weight per flower at each node position for the bearer lengths between 1 and 5 nodes for hedge pruned <i>Vitis vinifera</i> cv. Cabernet Sauvignon vines at Coonawarra (2005).....	39
3.11 Average weight per berry at each node position for the bearer lengths between 1 and 5 nodes for hedge pruned <i>Vitis vinifera</i> cv. Cabernet Sauvignon vines at Coonawarra (2005).....	40
3.12 Average weight pre-flowering at each node position for the bearer lengths between 1 and 5 nodes for hedge pruned <i>Vitis vinifera</i> cv. Cabernet Sauvignon vines at Coonawarra (2005).....	41
3.13 Average yield per bearer pre-harvest for the bearer lengths between 1 and 5 nodes for hedge pruned <i>Vitis vinifera</i> cv. Cabernet Sauvignon vines at Coonawarra (2005)	42
3.14 Figure 3.14 Effect of bearer node number on the proportion of fruitful, non-fruitful and blind nodes per bearer pre-flowering for the bearer lengths between 1 and 5 nodes for hedge pruned <i>Vitis vinifera</i> cv. Cabernet Sauvignon vines at Coonawarra (2005)	43
3.15 a,b,c. One hundred per cent stacked columns showing the range of node positions at which inflorescences arose on each shoot, based on the location of the shoot from the base of the bearer for hedge pruned <i>Vitis vinifera</i> cv. Cabernet Sauvignon vines at Coonawarra (2005).....	46
3.16 Mechanical hedge saw pruning: <i>Vitis vinifera</i> cv. Cabernet Sauvignon vines at Coonawarra (2005) pre-pruning (left) and post-pruning (right).....	52
4.1. Map of Limestone Coast Zone showing placement of vineyards in the study.....	64

ABSTRACT

This thesis presents results from two separate studies. First, the impact of bearer length on yield components within the canopy was investigated in season 2005/06, on a commercially-managed, mechanically-pruned vineyard of *Vitis vinifera* L. Cabernet Sauvignon in Coonawarra, South Australia. Pruning resulted in the retention of bearers with 1-7 nodes, with the weighted average bearer length being two nodes for the canopy. As bearers of one to five nodes in length were the most common, these were studied. Yield components (on a per shoot basis) were analysed according to the node position on the bearer at which the shoot arose. Both budburst and inflorescence number per node were highest at the distal node positions on each length bearer, even if the nodes were at the same positions from the base of the bearer and would normally be expected to have similar fertility. Budburst appeared to act by modifying inflorescence number per node based on the relative location of each node from the apex of the bearer. Shoots that arose from the most distal node positions had the highest flower number per inflorescence and berry number per bunch. Flower number per inflorescence was significantly higher on two-inflorescence shoots than single-inflorescence shoots. The relationship between bunch size and node position, unlike that between inflorescence number and node position, was dependent on bearer length. The relative size of the inflorescence appeared to be affected more so by the node position at which the shoot occurred on the bearer, as opposed to the actual node position on the shoot at which the inflorescence occurred. There was a positive, non-linear relationship between average fruit yield per bearer and bearer length. Although yield was highest from the bearer with the highest node number (five nodes), there was no significant difference in yield per bearer for the bearers of three to five nodes in length. If average bearer length was increased from two to three nodes, the potential yield gain per bearer is estimated at 38 per cent.

The second study presents results of correlations between bunch number and components of bunch weight (flower number and berry number) to investigate co-development of bunch number and bunch size. These data were collected from 4 vineyards in the Limestone Coast Zone of South Australia from *Vitis vinifera* L. Chardonnay, Shiraz and Cabernet Sauvignon during seasons 2002/03 to 2006/07. The significant correlations found between fertility and both bunch weight and flower number per inflorescence suggest that the same factors that affect bunch number in a particular season will also affect bunch size. When inflorescence primordia were initiated and differentiated

under cool conditions, actual bunches per node and flowers per inflorescence were low. Differences in climate between the vineyard sites were found to be minimal and therefore did not strongly affect the magnitude of the yield components at the vineyard sites. Cultural practices at each vineyard site were sufficiently variable to affect fertility levels. Genotype is thought to determine the range of flowers per inflorescence that a variety can potentially carry, whereas actual flower number per inflorescence is thought to be determined by inflorescence primordium initiation and differentiation temperatures, as well as temperatures during budburst. Despite significant correlations between flower number per inflorescence and berry number per bunch, flower number per inflorescence pre-flowering for Cabernet Sauvignon, Shiraz and Chardonnay is inversely related to actual percentage fruit set. This is possibly a survival mechanism for the grapevine as it allows the vine to maximise yield each season without detriment to its longevity. Bunches per vine accounted for the majority of the seasonal variation in yield per vine. Fluctuations in bunch number per vine (and therefore yield) are likely to be reduced by varying the number of nodes retained per vine according to the relative fruitfulness per node present pre-pruning. This practice is therefore likely to result in the seasonal variation of berries per bunch becoming a stronger driver of yield.

The commercial impacts of these studies are two-fold. Data presented will assist growers to understand the reasons for which their pruning regimes are affecting yield production and how these pruning regimes may be modified to achieve a target yield—particularly when growers are faced with seasons of low predicted fertility. In addition, data presented will allow growers to improve their crop forecasting accuracy, with a greater understanding of the link between bunch number and bunch size. In the current situation of oversupply in the wine industry, wineries are adopting a tough stance towards growers over-delivering on their grape contracts. Therefore, any assistance that can be provided to growers on improving accuracy of yield estimates will be beneficial both to the grower and winery.

DECLARATION

This work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution. To the best of my knowledge and belief, this work contains no material previously published or written by another person, except where due reference has been made in the text.

I give consent to this copy of my thesis, when deposited in the University Library, being made available for loan and photocopying, subject to the provisions of the Copyright Act 1968.

S.J. McLoughlin
28/02/09

ACKNOWLEDGEMENTS

I would like to extend my sincere appreciation to my two Supervisors, Associate Professor Peter Dry of The University of Adelaide and Dr Paul Petrie of Foster's Group for their encouragement, guidance and expertise throughout the last four years. My knowledge of statistics and command of the English language, amongst other things, have certainly benefited greatly from your input.

I want to acknowledge Allen Jenkins (Regional Manager, Limestone Coast South Vineyards – Foster's Group) who encouraged me to embark upon this Masters in the first place. Allen – I am grateful that you suggested that this might be 'the thing for me'! I have appreciated your continued support and interest in this work and allowing me to utilise company yield data. Hopefully some of the findings of this Thesis will help to refine management practices in Foster's Limestone Coast Vineyards going forward.

To the technical staff in the Limestone Coast Vineyards of Foster's Group (many of whom have come and gone), thank you for your patience and counting expertise – I know that you dread Novembers. I've utilised much data that we have all collected over the years and I wouldn't have been able to carry out this work if it was not for all of you.

Finally, to my wonderful family, Richard, Margaret, Kerry and Andrew, who have always been there to support me and to my friends – thank you for the continuous questions of 'when are you going to finish that Masters' and 'how's that Masters coming along'well it's finally done!