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.
The effect of coir particle size on yield of greenhouse tomatoes (*Lycopersicon esculentum* Mill.)

A thesis presented in partial fulfilment of the requirements for the degree of Master of Science (Horticultural Science) at Massey University, Turitea, New Zealand.

Damian Duggan-Jones

2012
ABSTRACT

Coir is a relatively new growing media, and little information is known of the relationship between particle size and particle size distribution on crop productivity. Particle size significantly affects the physical properties of coir, particularly the air-water relationships. The objectives are (1) to investigate the relationship water holding capacity has on total yield, fruit number and mean fruit weight of tomato (2) determine whether growth analysis could be used to test treatments prior to full scale growth trials in terms of predicting yields based on small sample sets of limited duration. Two yield trials, summer and winter trials, was designed to compare the yield of a tomato (*Lycopersicum esculentum*) crop grown in coir using a range of particle sizes, while a plant growth analysis was used to compare RGR, LAR, and NAR. Two coir sources were used throughout the trials. One source consisted of seven treatments based on combinations of small (S), medium (M) and large (L) size grade particles. The second source consisted of two ungraded coir products, P1 and P3. Two irrigation (low and high) frequencies were used. The seven treatments were based on particle size with differences in WHC (water holding capacity). A bioassay was used to compare tomato yield and RGR. The physical properties, governed by particle size, have an effect on tomato yield. The average yield for the winter yield trial was 2.14 and 2.38 kg per plant for SG and HK data while the average yield for the summer yield trial was 7.92 and 7.69 kg per plant. An increasing linear relationship exists between WHC and fruit yield per plant, as treatments increase in WHC so do their fruit yield per plant. A relationship was also found between the bioassay and tomato yield trial. Similar to the tomato yield trial, as WHC increased so did the RGR. The relationship between WHC and RGR may have commercial implications for both soilless media manufacturers and growers who require specific physical properties in terms of water and air availability for particular crop types.
ACKNOWLEDGEMENTS

This project was made possible by a number of contributors and I would like to give my deep thanks to all those concerned.

I would like to thank my family; Debbie, Michael and Robyn Duggan-Jones for their continued support and guidance. Their motivation and belief that I can accomplish anything in life became powerful contributions to me completing this study. My sincere thanks to my supervisors Dr. Mike Nichols and Dr. David Woolley, for their professional guidance and academic advice throughout the duration of my research work. Their expertise in the area helped tremendously. GTL Coir for their financial assistance and belief in the work that needed to be done.

I would also like to give my continued thanks to the staff at the Plant Growth Unit at Massey University for their valuable advice and friendship; manager Steve Ray and technicians Lindsey Sylva and Lesley Taylor. I further thank Akie Hirata for your friendship and moral support throughout my journey.
# TABLE OF CONTENTS

## ABSTRACT

- I

## ACKNOWLEDGEMENTS

- II

## TABLE OF CONTENTS

- III

## LIST OF TABLES

- IX

## LIST OF FIGURES

- XII

## LIST OF PHOTOS

- XVI

## CHAPTER 1: INTRODUCTION

- 1

## CHAPTER 2: LITERATURE REVIEW

- 3

  2.1 Coconut palm

  - 3

  2.2 Coir

  - 4

  2.3 Physical properties

  - 6

    2.3.1 Bulk density

    - 6

    2.3.2 Particle size distribution

    - 7

    2.3.3 AFP

    - 9

    2.3.4 Soil plant atmosphere

    - 10

    2.3.5 Water release/retention curves

    - 13

  2.4 Tomato physiology and greenhouse productivity

  - 16

    2.4.1 Hybrid Seed

    - 16

    2.4.2 Nutrition

    - 16
2.4.3 Controlling growth ................................................................. 17
2.4.4 Cultural practices ................................................................. 17
2.4.4.1 Wire training ................................................................. 18
2.4.4.2 Lower growing point .................................................. 19
2.4.4.3 Remove side shoots .................................................... 19
2.4.4.4 Leaf pruning ............................................................... 20
2.4.4.5 Fruit thinning .............................................................. 20
2.4.5 Flowering ................................................................. 21
2.4.6 Harvesting ................................................................. 22
2.4.7 Defects (physiological disorders) ........................................ 24
2.4.7.1 Cracking ................................................................. 24
2.4.7.2 Misshapen fruit, catface & puffiness) ......................... 25
2.4.7.3 BER (Blossom End Rot) ............................................. 25
2.4.8 Pest and Disease ............................................................ 28
2.5 Growth Analysis ................................................................. 30
2.5.1 Introduction ................................................................. 30
2.5.2 Absolute growth rate (AGR) ........................................... 31
2.5.3 RGR ................................................................. 31
2.5.4 NAR ................................................................. 32
2.5.5 LAR ................................................................. 33
2.5.6 Summary ................................................................. 35
CHAPTER 3: MATERIALS AND METHODS ................................................................. 36

3.1 Potting material ................................................................................................... 36

3.1.1 Size grade sourced coir ...................................................................................... 36

3.1.2 Hong Kong (HK) sourced coir ............................................................................ 37

3.1.3 Physical properties of coir.................................................................................. 37

3.1.4 Facilities .............................................................................................................. 38

3.2 Winter yield trial .................................................................................................. 40

3.3 Summer yield trial ............................................................................................... 41

3.4 Growth Analysis 1: Tall vs Short Pots................................................................. 42

3.5 Growth Analysis 2: Tall Pots only......................................................................... 42

3.6 Data collection and analysis................................................................................ 43

CHAPTER 4: RESULTS .............................................................................................. 44

4.1 Size grade physical properties summary ............................................................. 44

4.2 Hong Kong (HK) size grade .................................................................................. 44

4.3 Winter yield trial .................................................................................................. 46

4.3.1 Total yield (HK).................................................................................................. 46

4.3.2 Fruit number (HK) ............................................................................................. 47

4.3.3 Mean fruit weight (HK) ..................................................................................... 48

4.3.4 Total yield (SG).................................................................................................. 49

4.3.5 Fruit number (SG) ............................................................................................. 50

4.3.6 Mean fruit weight (SG)..................................................................................... 51

4.4 Summer yield trial............................................................................................... 52
4.4.1 Total yield (HK) ..................................................................................................... 52
4.4.2 Fruit number (HK) .............................................................................................. 53
4.4.3 Mean fruit weight (HK) ....................................................................................... 54
4.4.4 Total Yield (SG) ................................................................................................... 56
4.4.5 Fruit number (SG) .............................................................................................. 57
4.4.6 Mean fruit weight (SG) ....................................................................................... 58
4.4.7 Cumulative Yield (HK) ........................................................................................ 60
4.4.8 Cumulative Yield (SG) ........................................................................................ 61
4.4.9 Time to 50% total harvest (HK) ......................................................................... 62
4.4.10 Inner quartile range (HK) .................................................................................... 63
4.4.11 Time to 50% total harvest (SG) ........................................................................ 65
4.4.12 Inner quartile range (SG) ................................................................................... 66
4.5 Growth Analysis 1 (HK) ........................................................................................ 68
4.5.1 Relative growth rate (RGR) .................................................................................. 68
4.5.2 Leaf area ratio (LAR) .......................................................................................... 69
4.5.3 Net assimilation rate (NAR) ................................................................................. 70
4.6 Growth analysis 1 (SG) .......................................................................................... 71
4.6.1 Relative growth rate (RGR) .................................................................................. 71
4.6.2 Leaf area ratio (LAR) .......................................................................................... 72
4.6.3 Net assimilation rate (NAR) ................................................................................ 74
4.7 Growth Analysis 2 (SG) .......................................................................................... 75
4.7.1 Relative growth rate (RGR) .................................................................................. 75
4.7.2 Leaf area ratio (LAR) .......................................................... 76
4.7.3 Net assimilation rate (NAR) .................................................. 77
4.8 Correlations ........................................................................... 78
4.8.1 AFP vs WHC (HK) .............................................................. 78
4.8.2 AFP vs WHC (SG) .............................................................. 78
4.8.3 WHC vs Yield (SG) .............................................................. 79

CHAPTER 5: DISCUSSION ............................................................... 80
5.1 Tomato yield trial ................................................................. 80
5.1.1 Tx (time to x percentage of total harvest) parameters .............. 83
5.2 Growth Analysis ................................................................... 84
5.3 Correlations .......................................................................... 86
5.4 Coir source ........................................................................... 87

CHAPTER 6: CONCLUSION ......................................................... 89
6.1 Tomato yield trial ................................................................. 89
6.2 Growth analysis ................................................................. 89
6.3 Correlations .......................................................................... 90
6.4 Coir source ........................................................................... 91

CHAPTER 7: COMMENTS AND FUTURE DEVELOPMENTS .......... 92

CHAPTER 8: REFERENCES ......................................................... 96

APPENDIX 1: EXAMPLE STATISTICAL ANALYSIS .................. 103

Yield trial ................................................................................. 103
Total yield ............................................................................... 103
Time to 50% harvest ......................................................................................................... 105

Growth Analysis .................................................................................................................... 107

Relative growth rate ........................................................................................................ 107

APPENDIX 2: PHOTOS OF SUMMER YIELD TRIAL ................................................................. 109

APPENDIX 3: PHOTOS OF GROWTH ANALYSIS 2(SG) ............................................................ 112

APPENDIX 4: PAPER PRESENTED AT: INTERNATIONAL CONFERENCE & EXHIBITION ON SOILLESS CULTURE 2012 (SHANGHAI, CHINA) ................................................................. 113
LIST OF TABLES

TABLE 1. WORLD TOP TEN COUNTRIES BY COCONUT PRODUCTION (TONNES). ................................................. 4


TABLE 3. PHYSICAL PROPERTIES OF SIZE GRADE AND HONG KONG SOURCED COIR. PROPERTIES include mean values for water holding capacity (WHC) and air filled porosity (AFP) and significant differences (95% CI). SOURCE DUGGAN-JONES(2011) ........... 37

TABLE 4. THE RECIPE USED FOR THE STANDARD A AND B NUTRIENT SOLUTION. INGREDIENTS WERE diluted into 200L PLASTIC CONTAINERS FROM WHICH 20L CONTAINERS WERE USED FOR THE A AND B SOLUTION FOR THE SUMMER YIELD TRIAL ................................................................. 39

TABLE 5. PHYSICAL PROPERTIES OF SIZE GRADE AND HONG KONG SOURCED COIR. PROPERTIES include mean values for water holding capacity (WHC) and air filled porosity (AFP) and significant differences (95% CI). SOURCE DUGGAN-JONES(2011) ........... 44

TABLE 6. TOTAL YIELD PER PLANT OVER 2 IRRIGATION TREATMENTS INCLUDING THEIR MEANS AND LSD (95% CI). ......................................................................................................................... 46

TABLE 7. FRUIT NUMBER PER PLANT OVER 2 IRRIGATION TREATMENTS INCLUDING THEIR MEANS AND LSD (95% CI). ......................................................................................................................... 47

TABLE 8. MEAN FRUIT WEIGHT PER PLANT OVER 2 IRRIGATION TREATMENTS INCLUDING THEIR MEANS AND LSD (95% CI). ......................................................................................................................... 48

TABLE 9. TOTAL YIELD PER PLANT OVER 2 IRRIGATION TREATMENTS INCLUDING THEIR MEANS AND LSD (95% CI). ......................................................................................................................... 49

TABLE 10. FRUIT NUMBER PER PLANT OVER 2 IRRIGATION TREATMENTS INCLUDING THEIR MEANS AND LSD (95% CI). ......................................................................................................................... 50

TABLE 11. MEAN FRUIT WEIGHT PER PLANT OVER 2 IRRIGATION TREATMENTS INCLUDING THEIR MEANS AND LSD (95% CI). ......................................................................................................................... 51

TABLE 12. TOTAL YIELD PER PLANT OVER 2 IRRIGATION TREATMENTS INCLUDING THEIR MEANS AND LSD (95% CI). ......................................................................................................................... 52

TABLE 13. FRUIT NUMBER PER PLANT OVER 2 IRRIGATION TREATMENTS INCLUDING THEIR MEANS AND LSD (95% CI). ......................................................................................................................... 54
TABLE 14. MEAN FRUIT WEIGHT PER PLANT OVER 2 IRRIGATION TREATMENTS INCLUDING THEIR MEANS AND LSD (95% CI). ................................................................. 55

TABLE 15. TOTAL YIELD PER PLANT OVER 2 IRRIGATION TREATMENTS INCLUDING THEIR MEANS AND LSD (95% CI). ................................................................. 56

TABLE 16. FRUIT NUMBER PER PLANT OVER 2 IRRIGATION TREATMENTS INCLUDING THEIR MEANS AND LSD (95% CI). ................................................................. 58

TABLE 17. MEAN FRUIT WEIGHT PER PLANT OVER 2 IRRIGATION TREATMENTS INCLUDING THEIR MEANS AND LSD (95% CI). ................................................................. 59

TABLE 18. THE MEDIAN (Q2) OF TOTAL YIELD PER PLANT BETWEEN 7 SIZE GRADE AND 2 IRRIGATION TREATMENTS, WITH AN LSD OF 4.05 .................................................................. 62

TABLE 19. THE INNER QUARTILE RANGE (IQR) OF TOTAL YIELD PER PLANT BETWEEN 7 SIZE GRADE AND 2 IRRIGATION TREATMENTS, WITH AN LSD OF 4.80 .................................................................. 64

TABLE 20. THE MEDIAN (Q2) OF TOTAL YIELD PER PLANT BETWEEN 7 SIZE GRADE AND 2 IRRIGATION TREATMENTS, WITH AN LSD OF 5.06 .................................................................. 65

TABLE 21. THE INNER QUARTILE RANGE (IQR) OF TOTAL YIELD PER PLANT BETWEEN 7 SIZE GRADE AND 2 IRRIGATION TREATMENTS, WITH AN LSD OF 6.53 .................................................................. 67

TABLE 22. THE RELATIONSHIP BETWEEN RELATIVE GROWTH RATE (RGR) ON BOTH COIR AND POT HEIGHT TREATMENT. POT TREATMENTS CONTAINED THE SAME VOLUME WITH TALL POTS BEING TWICE THE HEIGHT OF THE SHORT POT. ................................................................. 68

TABLE 23. THE RELATIONSHIP BETWEEN LEAF AREA RATIO (LAR) ON BOTH COIR AND POT HEIGHT TREATMENT. POT TREATMENTS CONTAINED THE SAME VOLUME WITH TALL POTS BEING TWICE THE HEIGHT OF THE SHORT POT. ................................................................. 69

TABLE 24. THE RELATIONSHIP BETWEEN NET ASSIMILATION RATE (NAR) ON BOTH COIR AND POT HEIGHT TREATMENT. POT TREATMENTS CONTAINED THE SAME VOLUME WITH TALL POTS BEING TWICE THE HEIGHT OF THE SHORT POT. ................................................................. 70

TABLE 25. THE RELATIONSHIP BETWEEN RELATIVE GROWTH RATE (RGR) ON BOTH COIR AND POT HEIGHT TREATMENT. POT TREATMENTS CONTAINED THE SAME VOLUME WITH TALL POTS BEING TWICE THE HEIGHT OF THE SHORT POT. ................................................................. 71

TABLE 26. THE RELATIONSHIP BETWEEN LEAF AREA RATIO (LAR) ON BOTH COIR AND POT HEIGHT TREATMENT. POT TREATMENTS CONTAINED THE SAME VOLUME WITH TALL POTS BEING TWICE THE HEIGHT OF THE SHORT POT. ................................................................. 72
TABLE 27. THE RELATIONSHIP BETWEEN NET ASSIMILATION RATE (NAR) ON BOTH COIR AND POT
HEIGHT TREATMENT. POT TREATMENTS CONTAINED THE SAME VOLUME WITH TALL POTS
BEING TWICE THE HEIGHT OF THE SHORT POT. .............................................................. 74

TABLE 28. THE RELATIONSHIP BETWEEN RELATIVE GROWTH RATE (RGR) ON 7 SIZE GRADE (SG)
TREATMENTS.......................................................... .............................................................. 75

TABLE 29. THE RELATIONSHIP BETWEEN LEAF AREA RATIO (LAR) ON 7 SIZE GRADE (SG)
TREATMENTS.......................................................... .............................................................. 76

TABLE 30. THE RELATIONSHIP BETWEEN NET ASSIMILATION RATE (NAR) ON 7 SIZE GRADE (SG)
TREATMENTS.......................................................... .............................................................. 77

TABLE 31. WHC (WATER HOLDING CAPACITY), RGR (RELATIVE GROWTH RATE) AND TOMATO YIELD
PRODUCED FROM DIFFERENT SIZE GRADED COIR AND TWO IRRIGATION TREATMENTS. ........ 118
LIST OF FIGURES

FIG. 1. A CROSS SECTION OF A COCONUT INCLUDING THE EDIBLE FRUIT (COPRA). THE SKIN AND HUSK ARE CONSIDERED A BY-PRODUCT................................................................................................. 5

FIG. 2. COIR, FINE MESOPHYLL PARTICLES REMAIN AFTER THE EXTRACTION OF LONG FIBROUS STRANDS. PARTICLE SIZE DEPENDS ON HOW THE COIR WAS GRADED. THE SAMPLE ON THE LEFT CONTAINS GRADED COIR OF INCONSISTENT PARTICLE SIZE WHILE THE SAMPLE ON THE RIGHT HAS BEEN GRADED THROUGH A SIEVE OF KNOWN DIAMETER.............................................. 6

FIG. 3. A CUMULATIVE REPRESENTATION OF PARTICLE SIZE DISTRIBUTION FOR COIR THE DIAMETER RANGE OF THE PARTICLES (D). ....................................................................................... 8


FIG. 5. THE APPARATUS USED TO DETERMINE THE WATER RELEASE CURVE (HEINS APPARATUS). THE FUNNEL (SUBSTRATE CONTAINER) IS PART OF A SYSTEM WHICH CONNECTS TO A MEASURING TUBE VIA A PLASTIC TUBE. A RULER IS INCLUDED TO WORK OUT THE HYDRAULIC HEAD. .......... 14


FIG. 7. AN OVERVIEW OF COMMON CULTURAL PRACTICES WHICH NEED TO BE PERFORMED REGULARLY TO ENSURE OPTIMUM PRODUCTION............................................................. 18

FIG. 8. SOLANUM SPECIES INCLUDING TOMATO PRODUCE A VARIETY OF TRICHOMES ON THE SURFACE OF LEAVES, STEMS AND FLOWERS PARTS. TYPE FOUR AND TYPE SIX TRICHOMES ARE ASSOCIATED WITH HIGH ANTHROPOD CONTROL................................................................. 29

FIG. 9. THE RELATIONSHIP BETWEEN GROWTH PARAMETERS RGR (RELATIVE GROWTH RATE), LAR (LEAF ARE RATIO), LWR (LEAF WEIGHT RATIO) AND SLA (SPECIFIC LEAF AREA). ....................... 34

FIG. 10. THE GREENHOUSE LAYOUT USED FOR THE TWO TOMATO YIELD TRIALS. THE UPPER HALF CONSISTS OF THE HONG KONG TRIAL WHILE THE BOTTOM HALF THE SIZE GRADE TRIAL. THE LAYOUT CONSISTS OF 2 IRRIGATION FREQUENCIES (6 IRRIGATIONS AND 3 IRRIGATIONS). GUARD ROWS (G) WERE PLACED ON EITHER END OF THE GREENHOUSE. BLANKS (B), CONTAINING UNGRADED COIR, WHERE ADDED TO FILL THE COUPLE OF GAPS IN BOTH TRIALS.... 39
FIG. 11. SIZE GRADE DISTRIBUTION GRAPH FOR HONG KONG (HK) SAMPLE SET .............................. 45

FIG. 12. RELATIONSHIP BETWEEN WHC (WATER HOLDING CAPACITY) AND TOTAL YIELD OBTAINED PER PLANT BETWEEN TWO IRRIGATION TREATMENTS. ........................................................... 46

FIG. 13. RELATIONSHIP BETWEEN WHC (WATER HOLDING CAPACITY) AND FRUIT NUMBER OBTAINED PER PLANT BETWEEN TWO IRRIGATION TREATMENTS. ......................................................... 47

FIG. 14. RELATIONSHIP BETWEEN WHC (WATER HOLDING CAPACITY) AND MEAN FRUIT WEIGHT PER PLANT BETWEEN TWO IRRIGATION TREATMENTS. ............................................................ 48

FIG. 15. RELATIONSHIP BETWEEN WHC (WATER HOLDING CAPACITY) AND TOTAL YIELD OBTAINED PER PLANT BETWEEN TWO IRRIGATION TREATMENTS. ........................................................... 49

FIG. 16. RELATIONSHIP BETWEEN WHC (WATER HOLDING CAPACITY) AND FRUIT NUMBER OBTAINED PER PLANT BETWEEN TWO IRRIGATION TREATMENTS. ......................................................... 50

FIG. 17. RELATIONSHIP BETWEEN WHC (WATER HOLDING CAPACITY) AND MEAN FRUIT WEIGHT PER PLANT BETWEEN TWO IRRIGATION TREATMENTS. ............................................................ 51

FIG. 18. RELATIONSHIP BETWEEN WHC (WATER HOLDING CAPACITY) AND TOTAL YIELD OBTAINED PER PLANT BETWEEN TWO IRRIGATION TREATMENTS. ........................................................... 53

FIG. 19. RELATIONSHIP BETWEEN WHC (WATER HOLDING CAPACITY) AND FRUIT NUMBER OBTAINED PER PLANT BETWEEN TWO IRRIGATION TREATMENTS. ......................................................... 54

FIG. 20. RELATIONSHIP BETWEEN WHC (WATER HOLDING CAPACITY) AND MEAN FRUIT WEIGHT PER PLANT BETWEEN TWO IRRIGATION TREATMENTS. ............................................................ 55

FIG. 21. RELATIONSHIP BETWEEN WHC (WATER HOLDING CAPACITY) AND TOTAL YIELD OBTAINED PER PLANT BETWEEN TWO IRRIGATION TREATMENTS. ........................................................... 57

FIG. 22. RELATIONSHIP BETWEEN WHC (WATER HOLDING CAPACITY) AND FRUIT NUMBER OBTAINED PER PLANT BETWEEN TWO IRRIGATION TREATMENTS. ......................................................... 58

FIG. 23. RELATIONSHIP BETWEEN WHC (WATER HOLDING CAPACITY) AND MEAN FRUIT WEIGHT PER PLANT BETWEEN TWO IRRIGATION TREATMENTS. ............................................................ 59

FIG. 24. A SIGMOIDAL YIELD CURVE OVER 85 DAYS BETWEEN 2 IRRIGATION TREATMENTS. THE SIGMOIDAL CURVE INDICATES 3 DISTINCT PHASES. PHASE 1 (P1) RAPIDLY INCREASES UNTIL DAY 36 WHERE, PHASE 2 (P2), A GRAND PERIOD OF GROWTH OR LINEAR PHASE IS REACHED. THIS LINEAR PHASE CONTINUES UNTIL DAY 43 WHERE PHASE 3 (P3) IS REACHED WHERE CUMULATIVE YIELD DECLINES. ..................................................................................... 60

FIG. 25. A SIGMOIDAL YIELD CURVE OVER 85 DAYS BETWEEN 2 IRRIGATION TREATMENTS. THE SIGMOIDAL CURVE INDICATES 3 DISTINCT PHASES. PHASE 1 (P1) RAPIDLY INCREASES UNTIL
DAY 36 WHERE, PHASE 2 (P2), A GRAND PERIOD OF GROWTH OR LINEAR PHASE IS REACHED. THIS LINEAR PHASE CONTINUES UNTIL DAY 43 WHERE PHASE 3 (P3) IS REACHED WHERE CUMULATIVE YIELD DECLINES. ........................................................................................................ 61

FIG. 26. COMPARING THE RELATIONSHIP BETWEEN WATER HOLDING CAPACITY (WHC) AND THE DAYS TAKEN TO COMPLETE THE MEDIAN (Q2) OVER 2 IRRIGATION TREATMENTS. THE MEDIAN MEASURES THE TIME TAKEN TO COMPLETE 50% OF TOTAL YIELD. .................... 63

FIG. 27. THE INNER QUARTILE RANGE (IQR) COMPARING WATER HOLDING CAPACITY (WHC) AND THE DAYS TAKEN USING 2 IRRIGATION TREATMENTS. IQR MEASURES THE DIFFERENCE BETWEEN Q1 AND Q3 WHICH ACCOUNTS FOR THE MIDDLE 75% OF TOTAL YIELD. ............... 64

FIG. 28. COMPARING THE RELATIONSHIP BETWEEN WATER HOLDING CAPACITY (WHC) AND THE DAYS TAKEN TO COMPLETE THE MEDIAN (Q2) OVER 2 IRRIGATION TREATMENTS. THE MEDIAN MEASURES THE TIME TAKEN TO COMPLETE THE 50% OF TOTAL YIELD...................... 66

FIG. 29. THE INNER QUARTILE RANGE (IQR) COMPARING WATER HOLDING CAPACITY (WHC) AND THE DAYS TAKEN USING 2 IRRIGATION TREATMENTS. IQR MEASURES THE DIFFERENCE BETWEEN Q1 AND Q3 WHICH ACCOUNTS FOR THE MIDDLE 75% OF TOTAL YIELD........... 67

FIG. 30. THE RELATIVE GROWTH RATE (RGR) FOR TWO POT TREATMENTS (SHORT AND TALL) OVER 7 COIR TREATMENTS. ......................................................................................................... 68

FIG. 31. LEAF AREA RATIO (LAR) FOR TWO POT TREATMENTS (SHORT AND TALL) OVER 7 SIZE GRADE TREATMENTS. ............................................................................................................. 69

FIG. 32. THE NET ASSIMILATION RATE (NAR) FOR TWO POT TREATMENTS (SHORT AND TALL) OVER 7 COIR TREATMENTS. ............................................................................................................... 70

FIG. 33. THE RELATIVE GROWTH RATE (RGR) FOR TWO POT TREATMENTS (SHORT AND TALL) OVER 7 COIR TREATMENTS. ............................................................................................................... 72

FIG. 34. LEAF AREA RATIO (LAR) FOR TWO POT TREATMENTS (SHORT AND TALL) OVER 7 SIZE GRADE TREATMENTS. ............................................................................................................. 73

FIG. 35. THE NET ASSIMILATION RATE (NAR) FOR TWO POT TREATMENTS (SHORT AND TALL) OVER 7 COIR TREATMENTS. ............................................................................................................... 74

FIG. 36. THE RELATIVE GROWTH RATE (RGR) COMPARED AGAINST SIZE GRADE TREATMENTS WITH VARIOUS WHC (% VOL). ........................................................................................................ 75

FIG. 37. THE LEAF AREA RATIO (LAR) COMPARED AGAINST SIZE GRADE TREATMENTS WITH VARIOUS WHC (% VOL). ........................................................................................................ 76
FIG. 38. THE NET ASSIMILATION RATE (NAR) COMPARED AGAINST SIZE GRADE TREATMENTS WITH VARIOUS WHC (% VOL) ........................................................................................................ 77

FIG. 39. THE CORRELATION BETWEEN AFP (AIR FILLED POROSITY) AND WHC (WATER HOLDING CAPACITY) ........................................................................................................ 78

FIG. 40. THE CORRELATION BETWEEN AFP (AIR FILLED POROSITY) AND WHC (WATER HOLDING CAPACITY) ........................................................................................................ 79

FIG. 41. THE CORRELATION BETWEEN RGR (RELATIVE GROWTH RATE) AND YIELD PER PLANT (Kg). HARVEST 2 DATA, SG SOURCE. ........................................................................................................ 79
LIST OF PHOTOS

PHOTO. 1. HYBRID ALBARON SEEDS WERE PROPAGATED IN ROCKWOOL CUBES ON AN EBB AND FLOW
SYSTEM UNTIL SUCH TIME AS THE ROOTS BEGAN EMERGING FROM THE BASE OF THE
CUBE. .............................................................................................................................. 109

PHOTO. 2. A WEEK LATER ON THE 2ND OF SEPTEMBER, SEEDLINGS WERE TRANSFERRED TO THEIR
PLASTIC BAGS CONTAINING THE 7 SIZE GRADE TREATMENTS ........................................ 109

PHOTO. 3. SEEDLINGS ESTABLISHED AND READY FOR WIRE SUPPORT .................................. 110

PHOTO. 4. ON THE 3RD OCTOBER 2011 FLOWERING WAS UNDERWAY AND SUPPORTED BY STRING.... 110

PHOTO. 5. A MONTH AND A HALF LATER, ON THE 23RD NOVEMBER 2001, FRUIT BEGAN RIPENING
AND PLANTS WERE TOPPED WHEN THEY REACHED THE TOP WIRE OF 2M....................... 111

PHOTO. 6. WITH HARVESTING WAS WELL UNDERWAY. KING FRUIT WERE NOT REMOVED AND FRUIT
THINNING IGNORED. NO CHEMICAL SPRAYS WERE USED THROUGHOUT THE GROWTH
TRIAL. BIOLOGICAL CONTROL AGENT (ENCARSIA FORMOSA) WAS USED TO CONTROL
APHID POPULATIONS, AND BUMBLEBEES WERE INTRODUCED TO AID POLLINATION.......... 111

PHOTO. 7. THIS PHOTO WAS TAKEN A WEEK AFTER THE FIRST HARVEST WHEN 1ST TRUE LEAVES
APPEARED ...................................................................................................................... 112

PHOTO. 8. THIS PHOTO WAS TAKEN PRIOR TO THE SECOND DESTRUCTIVE HARVEST .............. 112