



**UNIVERSITI PUTRA MALAYSIA**

**ROOT RESTRICTION FOR GROWTH CONTROL AND  
PRECOCITY IN STARFRUIT (A VERRHOA CARAMBOLA L.)**

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**ROOT RESTRICTION FOR GROWTH CONTROL AND  
PRECOCITY IN STARFRUIT  
(*AVERRHOA CARAMBOLA* L.)**

**by**

**ZAINUDIN HAJI MEON**

**Dissertation Submitted in Fulfilment of the Requirements for the Degree  
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**All Praise for Allah and all Knowledge is His**



Abstract of dissertation submitted to the Senate of Universiti Putra Malaysia in fulfilment of the requirements for the degree of Doctor of Philosophy.

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Starfruit (*Averrhoa carambola*) is an important fruit grown commercially in Malaysia. High rainfall and plentiful sunshine of the humid tropic usually promotes abundant shoot growth. Tree height increment is also tremendously fast. These conditions could lead to increase vegetative growth. Innovative technique is therefore needed to control vegetative vigour. Root restriction offers an effective and safe method of reducing tree size and canopy development. The main objective of this research is to study the response of starfruit to root restriction treatments under in the glasshouse and field condition.

Root restriction studies have previously been conducted mainly in starfruit, they were preceded by preliminary studies on apple (*Malus domestica*) and pear (*Pyrus communis*) in the United Kingdom. Preliminary studies in apple grown in different container shapes and volumes showed that root and shoot growth



responded to both container dimensions and their interactions. Large volumes (12 litre) with high pot depths enhanced root growth, thereby increasing shoot growth. However, effects of root growth restriction were observed when container shape or volume was reduced resulting in decreased root and shoot growth, and nutrient levels. Root : shoot ratio remained consistent irrespective of changes in container volume or shape.

Studies on pear trees (*Pyrus communis*) subjected to different shapes and volumes of porous root restrictive membrane suggested that reduction in soil volume to 91 litres resulted in 35 and 38% reduction in girth increment and shoot length, respectively. Fruitset and average weight per fruit were unaffected, but leaf P concentration was reduced during the first year of planting.

Similar treatments tested on starfruit (*Averrhoa carambola*) grown in different container shapes and volumes indicated that growth responded mostly to container volumes. Root and shoot growth reduced with decrease in container volume. Detailed root studies using root observation chambers showed that reduction in chamber volume decreased root branching and root elongation but root length density (RLD) increased although coarse root length and root tip density did not change. Root surface area (RSA) was also reduced when root chamber volume decreased. It was concluded that the reduction in shoot growth was the result of reduced root growth and development.

Root anatomical studies showed that small and limited container volumes resulted in smaller, compacted and suberized cells near the root tips. Similarly, root diameter size and vessel size were reduced. All these phenomenon have proven that root restriction caused a reduction in shoot growth.

Reduction in container volumes from 24- to 3-litre enhanced flowering by 60 days. Sap flow velocity decreased from 22.3 to 9.5 cm hr<sup>-1</sup> while leaf water potential became more negative (-1.2 MPa to - 2.2 MPa) when container volume was reduced by eight folds.

Field studies using different shapes and volumes of porous root restrictive membrane revealed that all root-restricted plants reduced plant height, stem diameter, total leaf area and leaf number by 9.4, 12, 67 and 48%, respectively when compared to non restricted plants. Flowering was enhanced but fruitset was unaffected. The average first-year yield for both varieties of B10 and B17 was 19.6 tons per ha. and no nutrient deficiency symptom was detected.

All these results revealed that reduced plant size and earlier flowering in starfruit could be achieved by controlling container or soil volumes. Therefore, root restriction technique should be recommended for controlling plant vigour and inducing early flowering in starfruit.

Abstrak disertasi yang dikemukakan kepada Senat Universiti Putra Malaysia bagi memenuhi syarat untuk mendapatkan ijazah Doktor Falsafah.

**PEMBATASAN AKAR UNTUK MENGAWAL TUMBESARAN DAN  
MENGALAKKAN KEMATANGAN TERHADAP BELIMBING BESI  
(*AVERRHOA CARAMBOLA* L.).**

Oleh

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Tanaman belimbing besi (*Averrhoa carambola*) adalah tanaman komersil yang penting di Malaysia. Curahan hujan yang tinggi serta cahaya matahari yang banyak dikawasan tropika mengalakkan pertumbuhan pucuk yang sangat subur. Ketinggian pokok pula menjadi terlalu cepat. Kesemuanya ini meningkatkan kos pengeluaran. Pembatasan akar adalah cara yang efektif dan selamat untuk mengawal tumbesaran tampang. Objektif utama penyelidikan ini ialah untuk mengkaji pengurangan saiz pokok dan perkembangan kanopi tanaman belimbing besi dengan kaedah pembatasan akar yang dijalankan dirumahkaca dan diladang.

Kajian pembatasan akar telah dijalankan terhadap belimbing besi. Walaubagaimanapun, kajian awalan telah dijalankan keatas epal (*Malus domestica*) dan pir (*Pyrus communis*) di United Kingdom. Kajian terhadap epal yang ditanam di dalam beberapa rupabentuk dan isipadu bekas menunjukkan



pertumbuhan akar dan pucuk dipengaruhi oleh kedua-dua faktor bekas dan interaksi diantaranya. Rupabentuk bekas mempunyai isipadu yang besar (12 liter) dan kedalaman yang tinggi menggalakkan pertumbuhan akar dan penambahan pertumbuhan pucuk. Tetapi, kesan pembatasan akar dilihat apabila rupabentuk atau isipadu bekas mempunyai kedalaman yang rendah menghasilkan pengurangan akar, pertumbuhan pucuk serta nutrien. Nisbah akar kepada pucuk menjadi tetap walaupun isipadu bekas bertambah atau rupabentuk bertukar.

Kajian pembatasan akar terhadap pir (*Pyrus communis*) dengan menggunakan lapisan membran berbagai bentuk dan isipadu menunjukkan bahawa pengurangan isipadu tanah kepada 91-litre mengurangkan peningkatan lilitan batang dan pemanjangan pucuk masing-masing sebanyak 35 dan 38%. Set buah dan purata berat buah tidak terganggu, tetapi kandungan P pada daun berkurangan.

Perlakuan yang sama terhadap belimbing besi (*Averrhoa carambola*) yang ditanam di dalam bekas yang mempunyai rupabentuk dan isipadu yang berbeza menunjukkan pertumbuhan tanaman lebih banyak dipengaruhi oleh isipadu bekas. Pertumbuhan akar dan pucuk menurun apabila isipadu bekas berkurangan. Kajian terperinci dengan menggunakan kotak pemerhatian menunjukkan pertumbuhan kedua-dua akar dan pucuk, pendahanan akar, pemanjangan akar dan luas permukaan akar berkurangan apabila isipadu berkurangan. Keputusan di buat bahawa pengurangan pertumbuhan pucuk berlaku disebabkan pengurangan pertumbuhan dan perkembangan akar.



Kajian anatomi akar menunjukkan isipadu bekas yang kecil dan terhad mempercepatkan pembatasan akar serta mengakibatkan sel menjadi kecil, rapat dan menebal pada penghujung akar. Isi bekas yang kecil mengurangkan garispusat akar dan saiz 'vessel'. Fenomena ini membuktikan pembatasan akar mengurangkan tumbesaran pucuk.

Pengurangan bekas isipadu dari 24 ke 3 liter mempercepatkan masa berbunga sebanyak 60 hari. Kelajuan 'sap flow' berkurangan dari 22.3 ke 9.5 cm sejam dan ketegasan air daun meningkat kepada lebih negatif dari -1.2 ke -2.2 MPa apabila isipadu bekas berkurangan sebanyak lapan kali ganda.

Kajian diladang menggunakan lapisan membran berbagai bentuk dan isipadu menunjukkan semua pokok mengalami pengurangan ketinggian pokok, garispusat batang, jumlah keluasan daun dan bilangan daun masing masing sebanyak 9.4, 12, 67 dan 48% berbanding dengan pokok yang tiada membran. Pembungaan dipercepatkan manakala setbuah tidak terganggu. Purata hasil bagi klon B10 dan B17 pada tahun pertama ialah 19.6 ton setiap ha. dan tiada pengurangan pemakanan pada daun.

Keputusan ini menunjukkan saiz tanaman berkurangan dan pengalakkan bunga berlaku melalui pengurangan isipadu bekas. Oleh itu, teknik pembatasan akar adalah dicadangkan untuk mengawal pertumbuhan tanaman keseluruhannya serta mengalakkan kematangan tanaman belimbing.

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## TABLE OF CONTENTS

	<b>Page</b>
<b>ABSTRACT</b> .....	<b>ii</b>
<b>ABSTRAK</b> .....	<b>v</b>
<b>ACKNOWLEDGMENTS</b> .....	<b>viii</b>
<b>APPROVAL</b> .....	<b>x</b>
<b>DECLARATION</b> .....	<b>xi</b>
<b>LIST OF TABLES</b> .....	<b>xv</b>
<b>LIST OF FIGURES</b> .....	<b>xix</b>
<b>LIST OF PLATES</b> .....	<b>xxi</b>
 <b>CHAPTER</b>	
<b>I INTRODUCTION</b> .....	<b>1</b>
Hypotheses .....	<b>5</b>
Objectives .....	<b>5</b>
<b>II LITERATURE REVIEW</b> .....	<b>6</b>
Growth Responses to Root Restriction .....	<b>6</b>
Shoot Growth .....	<b>6</b>
Yield Response .....	<b>8</b>
Physiological Responses of Plants to Root Restriction .....	<b>10</b>
Nutrient Uptake .....	<b>10</b>
Plant Water Relations .....	<b>14</b>
Leaf Gas Exchanges .....	<b>16</b>
Dry Matter Partitioning .....	<b>18</b>
Hormonal Regulation .....	<b>20</b>
Factors That Induce Root Growth Restriction .....	<b>21</b>
Limited Container Size .....	<b>22</b>
Soil Compaction .....	<b>24</b>
High Density Planting .....	<b>26</b>
Deficit Irrigation .....	<b>26</b>
Root Growth Responses That Ameliorate the Effects of Root Restriction .....	<b>27</b>
Physical Root Structures .....	<b>27</b>
Root Elongation .....	<b>29</b>



<b>III</b>	<b>EXPERIMENTALS .....</b>	<b>32</b>
1.	Preliminary Study on the Use of Different Container Shapes and Volumes on the Growth of Apple Seedlings .....	33
	Materials and Methods .....	33
	Experimental Design and Statistical Analysis .....	36
	Results .....	37
	Discussion .....	50
	Conclusions .....	54
2.	The Use of Different Shapes and Volumes of Porous Restrictive Membrane on Pear Trees in the Field .....	55
	Materials and Methods .....	56
	Experimental Design and Statistical Analysis .....	59
	Results .....	60
	Discussion .....	65
	Conclusions .....	68
3.	Glasshouse Study on the Growth, Physiological Responses and Total Nutrient Accumulation of Starfruit Grown in Different Container Shapes and Volumes .....	68
	Material and Methods .....	69
	Experimental Design and Statistical Analysis .....	73
	Results .....	74
	Discussion .....	91
	Conclusions .....	96
4A.	Glasshouse Study on the Root Growth Pattern and Development of Starfruit in Restricted Conditions .....	96
	Material and Methods.....	97
	Experimental Design and	100
	Results .....	102
	Discussion .....	111
	Conclusions .....	116
4B.	Root Anatomy and Xylem Vessel Distribution of Starfruit Grown in Limited Volumes .....	118
	Treatments .....	119
	Results .....	120
	Discussion .....	125
	Conclusions .....	128
5.	Effects of Root Restriction on Growth, Flowering and Water Uptake of Starfruit (Glasshouse Study) .....	129
	Material and Methods.....	130
	Experimental Design and Statistical Analysis .....	132
	Results .....	133
	Discussion .....	145



Conclusions .....	147
6. Effects of Porous Root Restrictive Membranes on Productivity of Starfruit Grown Under Field Conditions.....	149
Material and Methods.....	150
Experimental Design and Statistical Analysis .....	153
Results .....	154
Discussion .....	170
Conclusions .....	174
<b>IV GENERAL DISCUSSION AND CONCLUSIONS</b>	<b>175</b>
REFERENCES .....	181
APPENDICES.....	197
A1. Analyses of variance of apple seedlings grown in containers of different shapes and volumes .....	198
A2. Analyses of variance of pear plants grown in root restrictive membranes .....	205
A3. Analyses of variance of starfruit grown in two shapes and three volumes of container .....	209
A4. Analyses of variance of starfruit grown in three rooting volumes .....	220
A5. Analyses of variance of starfruit grown in four container volumes .....	228
A6. Analyses of variance of starfruit grown in root restrictive membranes .....	233
B. Weather and Soil data .....	239
C. Geotextiles data.....	251
BIOGRAPHICAL SKETCH .....	251



## LIST OF TABLES

<b>Table</b>		<b>Page</b>
1	Summary of Growth Response in Some Fruit Trees to Root Restriction	31
2	Spatial Characteristics of PVC Containers .....	35
3	Root Length (m/plant) at 8 and 16 Weeks of Growth of Apple Seedlings Planted in Different Container Shapes and Volumes .....	42
4	Root Dry Weight (g/plant) at 8 and 16 Weeks of Growth of Apple Seedlings Planted in Different Container Shapes and Volumes .....	43
5	Root : Shoot Ratio at 8, 16 and 24 Weeks of Growth of Apple Seedlings Planted in Different Container Shapes and Volumes.....	46
6	Crop Growth Rate (CGR) and Relative Growth Rate (RGR) at 16 to 24 weeks of Apple Seedlings Planted in Different Container Shapes and Volumes.....	48
7	Total Nutrient Accumulation (g/plant) at 8 Weeks of Apple Seedlings Grown in Different Container Shapes and Volumes .....	49
8	Total Nutrient Accumulation (g/plant) at 16 Weeks of Apple Seedlings Grown in Different Container Shapes and Volumes .....	51
9	Shapes and Volumes of Root Porous Membrane Used in the Planting Hole in the Experiment.....	57
10	Vegetative Shoot Growth of Pear at 12 Months Subjected to Root Restrictive Membrane.....	61
11	Leaf Nutrient Concentration (g/kg) of Pear Plants at 10 Months Subjected to Root Restrictive Membrane.....	63
12	Flowering of Pear per Branch at 12 Months Subjected to Root Restrictive Membrane.....	64
13	Harvested Fruits (no./plant), Total Fruit Weight (g/plant) and Average Fruit Weight (g/fruit) at 12 Months of Pear Plants Subjected to Root Restrictive Membrane .....	66



14	Root Dry Weight (g/plant) of Starfruit Seedlings Grown at 12, 18 and 24 weeks in Different Container Shapes and Volumes.....	79
15	Root Length (m/plant) of Starfruit Seedlings Grown at 12, 18 and 24 weeks in Different Container Shapes and Volumes.....	80
16	Root : Shoot Ratio of Starfruit Seedlings Grown at 12, 18 and 24 weeks in Different Container Shapes and Volumes.....	81
17	Stomatal Conductances ( $\text{mmol m}^{-2} \text{s}^{-1}$ ) at 12 to 23 weeks of Starfruit Seedlings Grown in Different Container Shapes and Volumes.....	83
18	Leaf Water Potential (-MPa) at 12 to 23 weeks of Young Starfruit Seedlings Grown in Different Container Shapes and Volumes.....	84
19	Crop Growth Rate (CGR) and Relative Growth Rate (RGR) (18 to 24 weeks) of Starfruit Seedlings Grown in Different Shapes and Volumes .....	85
20	Total Nutrient Accumulation (g/ plant) at 12 weeks of Young Starfruit Seedlings Grown in Different Container Shapes and Volumes.....	87
21	Total Nutrient Accumulation (g/ plant) at 18 weeks of Young Starfruit Seedlings Grown in Different Container Shapes and Volumes.....	89
22	Total Nutrient Accumulation (g/ plant) at 24 weeks of Starfruit Seedlings Grown in Different Container Shapes and Volumes.....	90
23	Stomata Number, Epidermal Cell Number (no.) and Leaf Area of Starfruit Plants Grown in Three Volumes of Root Observation Chambers .....	103
24	Root Length Density, Root Surface Area and Root Tip Density of Starfruit Plants Grown in Three Volumes of Root Observation Chambers .....	106

25	Coarse Root Length and Total Root Length of Starfruit Plants Grown for 120 Days Plants in Three Volumes of Root Observation Chambers.....	108
26	Partitioning Percentage and Root : Shoot Ratio of Starfruit Plants Grown in Three Volumes of Root Observation Chambers .....	109
27	Foliar Nutrient Concentration (g/kg) Analysis of Starfruit Plants Grown in Three Volumes of Root Observation Chambers.....	110
28	Mean Xylem Vessel Number and Total Vessel Number at Different Distances from Root Tips .....	124
29	Number of Flowers per Branch at Anthesis (AT), Full Bloom (FB), Swollen Bud and Flower Fresh Weight (FFW) .....	136
30	Leaf Water Potential, Soil Moisture Content (%) and Bulk Density (g/ cm <sup>3</sup> ).....	140
31	Biomass, Total Dry Weight (TRDW), Root : Shoot Ratio and Root Dry Weight(RDW) And Root Weight Density.....	144
32	Shapes and Volumes of Restrictive Root Membrane Used in the Planting Holes of Field Experiment.....	151
33	Plant Height (cm/ plant) of Starfruit Plants cv. B10 and B17 Grown in Porous Root Restrictive Membrane .....	156
34	Stem Diameter (mm /plant) of Starfruit Plants cv. B10 and B17 Grown in Porous Root Restrictive Membranes .....	157
35	Total Shoot Length (cm/plant) of Starfruit Plants cv. B10 and B17 Grown in Porous Root Restrictive Membrane .....	159
36	Shoot Number (number/plant)of Starfruit Plants cv. B10 and B17 Grown in Porous Root Restrictive Membrane .....	160
37	Total Leaf Area (m <sup>2</sup> /plant ) and Leaf Number (no./ plant) at 10 Months .....	162
38	Number of Inflorescences per Tree at 6 and 12 Months in Starfruit Plants cv. B10 and B17 Grown in Porous Root Restrictive Membranes .....	164
39	Number of Fruitlet per Branch of Starfruit Plants cv. B10 and B17 at 8 months Grown in Porous Root Restrictive Membranes.....	165





40	Harvestable Fruit Number of Starfruit Plants cv. B10 and B17 Grown in Porous Root Restrictive Membrane .....	167
41	Average Fruit Weight (g /fruit) of Starfruit Plants cv. B10 and B17 Grown in Porous Root Restrictive Membrane .....	168
42	Marketable Yield (g/ plant) of Starfruit Plants cv. B10 and B17 Grown in Porous Root Restrictive Membranes .....	169
43	Nutrient Concentration (g/kg) of Starfruit Plants cv. B10 and B17 at 10 Months Grown in Porous Root Restrictive Membrane ...	172



## LIST OF FIGURES

<b>Figure</b>		<b>Page</b>
1	Linear Relationship Between Pot Depth and Plant Height in Apple Seedlings.....	39
2	Linear Relationship Between Pot Depth and Leaf Area in Apple Seedlings.....	40
3	Linear Relationship Between Pot Depth and Root Length at 24 weeks of Growth in Apple Seedlings.....	44
4	Linear Relationship Between Pot Depth and Root Dry Weight at 24 Weeks of Growth in Apple Seedlings.....	44
5	Plant Height of Starfruit Seedlings Grown in Three Container Volumes. ....	76
6	Leaf Area of Starfruit Seedlings Grown in Three Container Volumes. ....	76
7	Total Dry Weight of Starfruit Seedlings Grown in Three Container Volumes.....	78
8	Root Length Density of Starfruit Seedlings Grown in Three Container Volumes. Means with similar letters are not significant at $p < 0.05$ .....	78
9	Nitrogen Root Uptake Efficiency (NRUE) of Starfruit Seedlings Grown in Three Container Volumes. Vertical bar indicate LSD not significant at $p < 0.05$ .....	92
10	Linear Relationship Between Root Length and Leaf Area of Starfruit Grown in Different Container Shapes and Volumes At 24 Weeks indicate significant level at $P < 0.01$ .....	93
11	Plant Height of Starfruit Seedlings Grown in Three Volumes of Root Observation Chambers. ....	104
12	Internode Number of Starfruit Seedlings Grown in Three Volumes of Root Observation Chambers. ....	104



13	Linear Relationship Between Number of First-Order Root Laterals and Distant From Root Apex of Starfruit.....	107
14	Linear Relationship Between Root Elongation and Time of Emergence (week) of Starfruit. ....	107
15	Leaf Water Potential of Starfruit Seedlings ‘B10’ Grown in Root Observation Chambers. Vertical bar LSD at $p<0.05$ .....	113
16	Relationship between Plant Height and Root Elongation in Starfruit.....	117
17	Root Diameter of Starfruit Grown in Root Observation Chambers . Vertical bars indicate LSD $p<0.05$ .....	126
18	Number of Flowering Plants (a) and Flowering Intensity in Starfruit (b). Bars indicate level of significance $p<0.05$ . ....	134
19	Diurnal Sap Flow Velocity of Starfruit ‘B17’ Grown in Four Container Volumes. Arrow denotes time of irrigation. ....	138
20	Estimated Sap Flux of Starfruit ‘B17’ Grown in Four Container Volumes. Arrow denotes time of irrigation. ....	138
21	Percentage of Partitioning in Leaf, Stem and Root Dry Matter of Starfruit. Vertical bars indicate LSD at $p<0.05$ .....	142
22	Relationship between Trunk Cross-sectional Area and Mean Sapflux in Starfruit .....	148



## LIST OF PLATES

Plate	Page
1	Root Growth Tracing on Transparent Acetate Overlay. Each colour denotes weekly root elongation (Scale 1:10) ..... 101
2	Transverse Section of Starfruit Root. Vascular epidermis (vs), cortex (cx), endodermis (en), protoxylem (px), and metaxylem (mx) (at the region of 20 cm from root tip of 130-d). The protoxylem and metaxylem occupy the central stele. Bar = 25 $\mu\text{m}$ ..... 121
3	Root Segments taken from 7.5-litre Root Chamber 40 cm from Root Tip. Eight layers of suberized cells (sc) formed at the endodermis. Some protoxylems (px) were lignified. Tannin (t) formation was complete around the vascular epidermis. Bar = 50 $\mu\text{m}$ ..... 123
4	Root Segments taken from 22.5-litre Root Chamber 40 cm from Root Tip. Four to six layers of suberized cells formed at the endodermis (en). Protoxylem cells (px) were not lignified. Tannin (t) formation was not complete around the vascular epidermis. Bar = 100 $\mu\text{m}$ ..... 123



## CHAPTER I

### INTRODUCTION

There is a strong and expanding demand for tropical fruits in the local and international markets. This trend is likely to continue although marketing will be more competitive. The economics and social needs of fruit for local consumption are expected to increase by 5.3% per annum, i.e. an increase from the current consumption per capita of 40 kg to 72 kg per person by the year 2010. During the period 1991–2010, fruit production is targeted to grow at 6.3% per annum to reach a production level of 2.4 million tons (Department of Statistics, 1992).

Starfruit has been identified as one of the 16 fruit types to be promoted commercially by the growers. Due to high demand, this fruit has become popular in the local market and among consumers abroad (Izham and Abd Razak, 1992). Although the future prospects are bright, the cultivated area for starfruit is still small. In 1990, starfruit cultivation was recorded to be 1,533 ha while in 1996 it was 1,423 ha with production of 17.2 and 37.2 thousand tons of fresh fruits, respectively (Department of Agriculture, 1996). There are not many limitations to growing this fruit extensively due to its wide soil and climatic adaptability. However, there are many constraints that hinder increase in cultivation (Izham and Abd Razak, 1992). These constraints include major problems of high production cost in fertilization and fruit wrapping. Due to its vigorous and indeterminate vegetative growth, plant height increase is tremendously fast, leading to difficulty in hand-wrapping of the

fruits. Additionally, high rainfall and plentiful sunshine promote abundant shoot growth in the humid tropics.

Besides high production costs, the prospects for future fruit cultivation are hampered by labour and land shortages. Innovative techniques need to be investigated in order to develop productive fruit trees of manageable size, possibly by controlling vegetative vigour through effective and safe methods that can restrict tree size and canopy development, and increase production efficiency (Quinlan and Tobutt, 1990; Robinson et al., 1991). Otherwise, trees with large canopies are difficult to prune, spray and hand harvest fruits, and even have poor light distribution (Lakso et al., 1989).

Tree vigour control in perennial fruit trees has been achieved through the use of dwarfing rootstock, chemical control, scion type, root pruning and root restriction (Rogers and Beakbane, 1957; Richards and Rowe, 1977b). The classical example of root restriction by which plants are dwarfed by growing them in shallow containers with small soil volume is the bonsai trees (Brace, 1904; Tukey, 1964; Erez, 1982). Physical restriction of the tree roots has proven beneficial results, such as reduced tree size and increased precocity (Ferree, 1981; Schupp and Ferree, 1988; Erez et al., 1992). Plant size control through root restriction has been reported to be effective in large and fast growing fruit trees (Ferree et al., 1992).

Although there are numerous chemicals that can be used to retard vegetative growth (Atkinson and Crisp 1980; Ferree, 1989); these chemicals have many

