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by

ZAINUDIN HAJI MEON

Dissertation Submitted in Fulfilment of the Requirements for the Degree of Doctor of Philosophy in the Faculty of Agriculture Universiti Putra Malaysia April 2001

UPM

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.

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

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April 2001

Chairman: **Professor Wong Kai Choo, Ph.D.**

Faculty: **Agriculture**

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 (*Pyurus 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^{-1} 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

ZAINUDIN BIN HAJI MEON

April 2001

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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 pertumbesaran 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

pertumbesaran 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 pertumbesaran akar dan penambahan pertumbesaran pucuk. Tetapi, kesan pembatasan akar dilihat apabila rupabentuk atau isipadu bekas mempunyai kedalaman yang rendah menghasilkan pengurangan akar, pertumbesaran 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 pertumbesaran tanaman lebih banyak dipengaruhi oleh isipadu bekas. Pertumbesaran akar dan pucuk menurun apabila isipadu bekas berkurangan. Kajian terperinci dengan menggunakan kotak pemerhatian menunjukkan pertumbesaran kedua-dua akar dan pucuk, pendahanan akar, pemanjangan akar dan luas permukaan akar berkurangan apabila isipadu berkurangan. Keputusan di buat bahawa pengurangan tumbesaran pucuk berlaku disebabkan pengurangan pertumbesaran 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 pertumbesaran tanaman keseluruhannya serta mengalakkan kematangan tanaman belimbing.

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I certify that an Examination Committee met on 9th April 2001 to conduct the final examination of Zainudin bin Haji Meon on his Doctor of Philosophy thesis entitled "Root Restriction for Growth Control and Precocity in Starfruit (*Averrhoa carambola* L.) in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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This thesis submitted to the Senate of Universiti Putra Malaysia has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy.

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations, which have been duly acknowledged. I also declare that it has not been previously or currently submitted for any other degree at UPM or other institutions.

ZAINUDIN BIN HAJI MEON

Date: 8/5/2001

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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. Aditionally, 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