UNIVERSITI PUTRA MALAYSIA

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By

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YIELD AND QUALITY OF STARFRUIT (*Averrhoa carambola* CV. B10) UNDER PROTECTED CULTIVATION

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September 2007

Chairman : Associate Professor Mohd Ridzwan Abd. Halim, PhD

Faculty : Agriculture

Starfruit (*Averrhoa carambola*) is an important export fruit with an annual export value of RM30 million. The fruit is mainly exported to Europe. A critical constraint to the future expansion of the starfruit industry is its high labour requirement especially in wrapping of individual fruits, which takes up about 45% of the labour cost. Besides the labour requirement, from 2004 onward all fresh produce to be exported to Europe must meet the EUREPGAP requirement, which encompasses a good agriculture practice such as minimum usage of agrochemicals to maintain consumer confidence in food quality and safety. Thus cultivation of starfruit under protected structure offers an alternative production technique that can be considered.

Three experiments were conducted to study the agronomic performance of starfruit under protected structure. The first study was on the effect of crop load on plant's physiological performance, yield and fruit quality. The rate of

stomatal conductance and transpiration of matured leaf (35 day old) was significantly affected by the crop load treatments. The stomatal conductance of the high and medium crop load were 83-93 % higher ($P \leq 0.05$) than the low crop load. At the same time the transpiration rate of the middle and high crop load were 91 % higher than the lowest crop load ($P \leq 0.05$). The yield increased significantly ($P \leq 0.05$) with increase in crop load from 6.3 t/ha at the lowest to 22 t/ha at the highest crop load. The number of exportable size fruit increased with increase in number of 'M' and 'S' size fruits at the highest crop load.

Increase in crop load did not affect the fruit chemical properties such as soluble solids and ascorbic acid concentration. The fruit firmness was not significantly influenced by the crop load treatments. Thus maintaining crop load of starfruit up to 600 fruit per trees per harvesting season was able to increase exportable yield of starfruit without affecting fruit chemical properties and fruit firmness.

The second experiment was on the effect of fruit microenvironment on fruit development, qualities and nutrient concentration. The position of fruit under the tree canopy influenced the fruit microenvironment such as heat units and cumulative irradiance impinging on the fruits. The difference in heat units and cumulative irradiance had significant influence on fruit development, and fruit chemical properties. The fruits that were exposed to higher irradiance (PAR $m.m^{-2}$) were lower in fruit fresh weight ($P \leq 0.05$) compared to fruits

protected under the canopy. Thus at harvest these fruits were small and mainly of the 'S' size, while fruits protected under the tree canopy were bigger mainly of 'M' size.

Exposure to higher irradiance (PAR $m.m^{-2}$) did not influence the soluble solids concentration. Although exposure to higher irradiance could increase the ascorbic acid and carotenoid concentrations, the fruits lacked lustre. Exposure to higher heat unit caused a reduction in fruit calcium, which was the only element that was found to influence firmness of starfruit.

Hence a third study was conducted to determine the effect of foliar calcium on fruit quality improvement. Application of calcium onto the fruit during the early fruit development stage resulted in increase in fruit calcium concentration from 228 mg/kg to 287 mg/kg ($P \leq 0.05$). The calcium treated fruits had smaller cells with thicker cell walls when examined under the electron microscope. The application of calcium also increased the wing tip thickness ($P \leq 0.05$).

In conclusion, when cultivated under protected structure yield of starfruit can be increased by increasing the crop load up to 600 fruits per tree without adverse effect on fruit quality. Best quality fruits were those protected under the tree canopy. Application of the foliar calcium on to the fruit further enhanced fruit quality, resulting in fruit with thicker wings and increased in firmness.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Doktor Falsafah

HASIL DAN KUALITI BELIMBING (*Averrhoa carambola* CV. B10) DI BAWAH STRUKTUR PELINDUNG

Oleh

ZABEDAH MAHMOOD

September 2007

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Belimbing (*Averrhoa carambola*) merupakan tanaman eksport yang penting. Nilai eksport tahunannya dianggarkan RM30 juta dan destinasi utamanya ialah negara-negara Eropah. Masalah utama dalam perkembangan industri belimbing ialah keperluan tenaga buruhnya yang tinggi terutama untuk membungkus buah yang dianggarkan 45% dari keseluruhan kos tenaga buruh. Di samping itu, dari tahun 2004 semua produk segar yang dieksport ke negara-negara Eropah mesti memenuhi syarat-syarat EUREPGAP, yang merangkumi sistem amalan ladang yang mampan, seperti penggunaan racun kimia yang kurang demi mengekalkan keyakinan pelanggan. Tanaman dalam struktur pelindung merupakan satu alternatif yang perlu diteliti dan dikaji.

Tiga ujikaji telah dijalankan untuk memahami keperluan agronomi tanaman belimbing di bawah struktur pelindung. Kajian pertama merupakan kajian kelebatan buah ke atas fisiologi tumbuhan, hasil, dan kualiti buah. Kelebatan buah telah mempengaruhi kadar konduktans stomata dan kadar transpirasi daun matang (35 hari). Kadar konduktans stomata pada kelebatan tinggi dan sederhana adalah 83 – 93 % lebih tinggi dari kelebatan rendah ($P \leq 0.05$). Pada masa yang sama kadar transpirasi daun pada kelebatan sederhana dan tinggi adalah 91 % lebih tinggi daripada kelebatan rendah ($P \leq 0.05$). Hasil belimbing bertambah dari 6.3 tan sehektar pada kelebatan terendah kepada 22 tan sehektar pada kelebatan tinggi. Hasil eksport bertambah dengan bertambahnya bilangan buah saiz 'M' dan 'S'.

Kelebatan buah tidak memberi kesan kepada kandungan kimia buah seperti kandungan jumlah pepejal larut dan asid askorbik. Ciri-ciri fizikal buah seperti kerangupan buah tidak terjejas. Dengan menambah kelebatan buah pada tahap 600 biji buah sepokok, hasil eksport dapat ditambah tanpa menjejaskan kualiti buah.

Kajian kedua bertujuan untuk melihat kesan persekitaran mikro buah pada perkembangan buah, kualiti dan kandungan nutrien buah. Posisi buah memberi kesan kepada persekitaran mikro buah seperti unit haba dan jumlah irradians pada buah. Hal ini memberi kesan ketara kepada perkembangan buah, kandungan kimia dan kandungan nutrien. Buah yang terkena irradians (PAR $m.m^{-2}$) yang lebih tinggi adalah lebih kecil dengan berat segar yang

lebih rendah ($P \leq 0.05$) berbanding dengan buah yang terlindung di bawah kanopi. Dengan itu buah-buah ini kebanyakan kecil dengan saiz 'S'. Buah yang terlindung di bawah kanopi bersaiz 'M'.

Pendedahan kepada irradians yang tinggi juga tidak menjejas kandungan jumlah pepejal larut. Walaupun pendedahan kepada irradians dapat menambah kandungan asid askorbik dan karotin, buahnya kurang menarik kerana tidak berkilat. Pendedahan kepada unit haba yang tinggi pula menyebabkan pengurangan kandungan kalsium buah. Kalsium merupakan satu-satunya elemen yang mempengaruhi kerangupan buah.

Dengan itu kajian ketiga dijalankan untuk mengesan peranan semburan kalsium ke atas kualiti buah. Hasil kajian menunjukkan semburan kalsium telah menambahkan kandungan kalsium buah dari 228 mg/kg kepada 287 mg/kg ($P \leq 0.05$). Apabila dilihat di bawah mikroskop elektron, sel – sel buah yang disembur dengan kalsium adalah bersaiz lebih kecil dengan dinding sel yang lebih tebal berbanding buah yang tidak disembur. Ketebalan tip kepak buah telah bertambah ($P \leq 0.05$).

Hasil belimbing dapat ditambah apabila kelebatan buah ditambah sehingga 600 biji sepokok tanpa menjejaskan kualiti. Kualiti buah terbaik diperolehi dari buah yang terlindung di bawah kanopi. Semburan kalsium pada buah menghasilkan buah yang lebih rangup dengan tip kepak buah yang lebih tebal.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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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 concurrently submitted for any other degree at UPM or other institutions.

ZABEDAH BINTI MAHMOOD

Date: 10 October 2007

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CHAPTER 1

INTRODUCTION

The agriculture sector has been identified by the government to be 'The third engine of growth' after the industrial and services sectors. In the 8th Malaysia Plan the agriculture industry is further developed to ensure that it becomes more competitive and viable (Anon., 1999). The agriculture industry will be able to contribute significantly through increased food export and reduced import. As Malaysia is blessed with various species of fruits, a strategic plan has been made to improve the fruit industry. Various programs have been planned by the government to encourage commercial fruit cultivation. Efficient production technologies with products that meet the stringent market requirements are important to ensure the viability and competitiveness of the fruit industry both in the local and international markets.

The Third National Agriculture Plan (1998-2010) has identified fruits as an important commodity to be further developed and commercialised. The Ministry of Agriculture has made strategic plans in technology developments to increase productivity and viability of the fruit industry. Fifteen fruit types are given priority for development namely banana, papaya, pineapple,

melons, starfruit, mango, durian, jackfruit, rambutan, citrus, duku, langsat/dokong, cempedak, guava, ciku and mangosteen. Priority will be given to 10 (8+2) fruit types namely papaya, pineapple, melons, starfruit, mango, durian, jackfruit, citrus, guava and rambutan (Siti Hawa, 2003).

The area of fruit production has increased from 112,849 ha in 1984 to 315,667 ha in 2002 (Anon., 2004). Similarly the production has doubled from 638,100 t in 1985 to 1,234,000 t in the year 2000. The fruit production areas are mainly concentrated in the state of Johor, Pahang, Perak, Terengganu and Kelantan.

The demand for Malaysian tropical fruits in the international markets has shown an increasing trend over the past decades. Tropical fruits are popular for their peculiar taste, flavour, unique features and nutritious value. Starfruit is one example with its unique star shape when cut. The export value of our fruits has shown an increasing trend from RM154.68 million in 1991 to RM225.2 million in 2003. In 2003 papaya was our highest fruit export with a value of RM100 million, followed by watermelon RM42 million, and starfruit RM30 million (Anon.,2005).

Starfruit occupies about 0.41% of the total fruit production areas. The production area has decreased from 1,934 ha in 1993 to 1500 ha in 2005. This is mainly due to acute labour shortage especially in wrapping of fruits against fruit fly. The export value of fresh starfruit has been quite stable