



UNIVERSITI PUTRA MALAYSIA

***HEAT TRANSFER ANALYSIS OF TOMATO ROOT ZONE TEMPERATURE
COOLED BY CHILLED WATER IN TROPICAL GREENHOUSE***

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By

ANGELINA HO MEI YI

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, In
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April 2011

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Master of Science

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Chairman: Prof. Ir. Desa b. Ahmad, PhD, P.Eng

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The effect of root zone cooling on tomato root density was investigated under a greenhouse structure at Malaysian Agricultural Research and Development Institute (MARDI). Heat tolerance tomato variety was grown in a tropical greenhouse with pre-installed buried cooling pipes to chill the root zone. The experiment was conducted in a Split Plot Design with 4 temperature treatments, 15°C, 20°C, 25°C and the control (with no cooling pipes installed, approximately 30°C). Each treatment has 3 replicates. The results revealed that cooling the root zone to 25°C, the optimum temperature of tomato root volume production, increased the root volume by 32% at 16 Weeks after Transplanting (WAT), 7% at 20 WAT and 3% at 24 WAT. The study also shows that most of the roots are concentrated on the top layer which is first 10cm below the surface of planting media.

The thermal conductivity and thermal diffusivity of a planting media inside a tropical greenhouse was investigated and experimentally measured using the line heat source transient method. The apparatus used in this study was a modified thermal needle probe. The planting media used in this greenhouse was a combination of cocopeat: burnt rice husk: perlite with a ratio of 7:3:2 respectively. The thermal conductivity of cocopeat: burnt rice husk: perlite at a ratio of 7:3:2 with moisture content, 55.98% wet basis, and density, 0.08 g/cm^3 , was $0.1164 \text{ W/m}^\circ\text{C}$; and the thermal diffusivity was $1.1063 \times 10^{-4} \text{ m}^2/\text{s}$. At higher moisture content, the thermal conductivity of the planting media was $0.1560 \text{ W/m}^\circ\text{C}$; while the thermal diffusivity was $7.9029 \times 10^{-4} \text{ m}^2/\text{s}$.

Finally, a heat transfer analysis on the cooling system applied to the root zone was done. The effect of heat inside the greenhouse and the cooling effect from the pipes to the root zone temperature were studied. Calculations were done using a Solver for Principles of Heat Transfer. A heat transfer model was then developed to predict the root zone temperature using the conservation of energy concept where surface radiation heat transfer into the planting media is equals to the surface convection heat transfer of the chilled planting media.

$$\epsilon \times \sigma_{SB} \times (T_{in}^4 - T_4^4) = (T_4 - T_2) / R_{ku42}$$

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan ijazah Master Sains

ANALISIS PEMINDAHAN HABA SUHU ZON TANAMAN TOMATO YANG DISEJUKKAN DENGAN AIR DALAM RUMAH HIJAU TROPIKA

Oleh

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April 2011

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Pengaruh pendinginan zon akar tomato pada kepadatan akar telah diselidiki di bawah struktur rumah hijau di Institute Penyelidikan dan Pembangunan Pertanian Malaysia (MARDI). Varieti tomato yang tahan haba telah ditanam di rumah hijau tropika di mana paip air sejuk telah juga ditanam dalam bekas tanaman untuk menyejukkan zon akar. Eksperimen dijalankan dengan rekabentuk Split Plot. Empat perlakuan suhu, 15°C, 20°C, 25°C dan kawalan (tanpa paip pendingin dipasang, lebih kurang 30°C). Setiap rawatan ada tiga replikasi. Hasil kajian menunjukkan bahawa penyejukan bahagian akar ke 25°C meningkatkan pertumbuhan akar sebanyak 32% pada minggu ke-16 selepas ditanam di rumah hijau, 7% pada minggu ke-20 dan 3% pada minggu ke-24. Eksperimen ini juga menunjukkan bahawa ketumpatan akar bertumpu di bahagian atas iaitu 10cm dari permukaan media tanaman.

Kekonduksian terma dan keresapan terma media tanaman di dalam sebuah rumah hijau tropika telah diselidiki dan diukur menggunakan kaedah sumber panas garis transien. Alat yang digunakan untuk kajian ini adalah probe terma panjang yang diubahsuai. Media tanaman yang digunakan dalam rumah hijau ini merupakan kombinasi dari cocopeat: sekam padi dibakar: perlit dengan nisbah masing-masing 7:3:2. Kekonduksian terma kombinasi tersebut dengan kadar kandungan air 55.98% dan ketumpatan pukal $0.08g/cm^3$ adalah $0.1164 W/m^{\circ}C$, dan keresapan terma adalah $1.1063 \times 10^{-4} m^2/s$. Pada kadar kandungan air lebih tinggi, konduktiviti terma media tanaman adalah $0.1560 W/m^{\circ}C$; sedangkan keresapan terma adalah $7.9029 \times 10^{-4} m^2/s$.

Dalam kajian ini, analisis pemindahan haba pada sistem penyejukan pada zon akar telah dilakukan. Pengaruh haba dalam rumah hijau dan kesan pendinginan dari paip-paip ke suhu zon telah dipelajari. Perhitungan dilakukan dengan menggunakan Solver untuk Prinsip Heat Transfer. Model pemindahan haba telah dibangunkan untuk meramalkan suhu zon pertumbuhan akar menggunakan pemuliharaan konsep tenaga di mana permukaan radiasi pemindahan haba ke dalam media penanaman adalah sama dengan pemindahan haba perolakan media tanaman yang didinginkan.

$$\epsilon \times \sigma_{SB} \times (T_{in}^4 - T_4^4) = (T_4 - T_2) / Rku42$$

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DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institution.



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