UNIVERSITI PUTRA MALAYSIA

EFFECT OF TEMPERATURE AND RELATIVE HUMIDITY ON CROP YIELD IN TROPICAL GREENHOUSE WITH EVAPORATIVE COOLING SYSTEM

DIYANA BINTI JAMALUDIN

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By

DIYANA BINTI JAMALUDIN

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ABSTRACT

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October 2009

Chairman: Prof. Ir. Dr. Desa b. Ahmad, PhD
Faculty: Engineering

Tropical greenhouses require active evaporative cooling system such as pad-and-fan to ensure a suitable microclimate for crop production. Excess heat causes indoor temperature becoming hotter than desired resulting in detrimental effects to crop growth and production. Solar radiation intensity and outside temperature affect temperature and relative humidity level inside the greenhouse while wide gradients in temperature and relative humidity can cause problems for crop growth and production uniformity. Horizontal and vertical profiles of temperature and relative humidity inside the greenhouse were investigated. The study showed that temperature increased from evaporative pad to exhaust fans in a horizontal direction while relative humidity shows inverse pattern from temperature. In the vertical direction, temperature increased, while relative humidity decreased from lower level to the upper level. Similar pattern of

temperature and humidity distribution were observed inside the greenhouse, regardless of whether it was empty or with growing crop. The inside temperature with growing crops however, was slightly lower than the empty greenhouse. ANOVA results shows that in overall, temperature and relative humidity inside the greenhouse were uniform as there's no significance difference at 95% confidence interval.

The effects of temperature gradients inside the greenhouse and time of highest sunlight received on canopy diameter, head weight and head diameter were evaluated. Based on the results, most of the crop quality was better near the evaporative pad area as it was much cooler and east area which received highest morning sunlight (9am-11am). ANOVA test shows that crop yield inside the greenhouse was significantly different between each sections which shows that it was greatly affected by difference in temperature and relative humidity.

A mathematical equation representing the inside temperature was developed for both empty greenhouse and greenhouse with growing crops. Both measured and calculated values of inside temperature show strong agreement with R^2 = 0.996 for empty greenhouse and R^2 = 0.945 for greenhouse with growing crops. The t-test for calculated and measured inside temperature values of both conditions show no significant difference between them.

ABSTRAK

KESAN SUHU DAN KELEMBAPAN PADA HASIL TANAMAN DALAM RUMAH HIJAU TROPIKA DENGAN SISTEM PENYEJUKAN PENGEWAPAN

Oleh

DIYANA BINTI JAMALUDIN

Oktober 2009

Pengerusi : Prof. Ir. Dr. Desa b. Ahmad, PhD
Fakulti : Kejuruteraan

Rumah hijau tropika memerlukan sistem penyejukan pengewapan aktif seperti pad-dan-kipas untuk memastikan keadaan cuaca dalam rumah hijau sesuai bagi pengeluaran tanaman. Haba berlebihan boleh menyebabkan suhu di dalam rumah hijau menjadi lebih panas dari yang sepatutnya. Ini akan memberikan kesan negatif kepada pertumbuhan dan pengeluaran tanaman. Sinaran matahari mempengaruhi paras suhu dan kelembapan di dalam rumah hijau. Kecerunan yang besar bagi suhu dan kelembapan akan menimbulkan masalah terhadap keseragaman pengeluaran. Profil suhu dan kelembapan secara melintang dan menegak dalam rumah hijau tropika yang dilengkapi dengan sistem penyejukan menggunakan pad pengewapan-dan-kipas telah dikaji. Kajian menunjukkan suhu meningkat dari pad pengewapan ke kipas ekzos dalam arah melintang, manakala kelembapan menunjukkan corak songsang. Bagi arah menegak, suhu meningkat dari paras bawah ke paras atas. Kedua-dua rumah hijau kosong dan rumah hijau yang

mempunyai tanaman menunjukkan pola suhu dan kelembapan yang sama di dalam rumah hijau. Walaubagaimanapun, suhu di dalam rumah hijau yang mempunyai tanaman adalah lebih rendah dari rumah hijau yang kosong. Keputusan ANOVA menunujukkan secara keseluruhan, suhu dan kelembapan dalam rumah hijau adalah sekata tanpa sebarang perubahan signifikan pada tahap keyakinan 95%.

Kesan kecerunan suhu di dalam rumah hijau dan masa penerimaan cahaya matahari tertinggi bagi diameter kanopi, berat buah dan diameter buah telah dinilai. Hasil keputusan menunjukkan kebanyakan kualiti tanaman adalah lebih baik di bahagian pad pengewapan kerana lebih sejuk dan kawasan timur yang menerima cahaya matahari pagi tertinggi (9-11pagi). Keputusan ANOVA menunjukkan hasil tanaman dalam rumah hijau mempunyai perbezaan yang signifikan antara seksyen, di mana menunjukkan ia dipengaruhi oleh perbezaan suhu dan kelembapan.

Persamaan suhu di dalam rumah hijau kosong dan rumah hijau yang mempunyai tanaman telah dibangunkan. Didapati nilai ukuran dan pengiraan bagi suhu di dalam menunjukkan hasil yang sama dengan $R^2 = 0.996$ bagi model rumah kosong dan $R^2 = 0.945$ bagi rumah hijau yang mempunyai tanaman. Ujian T bagi nilai pengiraan dan ukuran menunjukkan tiada perbezaan ketara di antara nilai kedua-duanya.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master in Bioenvironmental Engineering.

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Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan ijazah Master Kejuruteraan Biopersekitaran.

KESAN SUHU DAN KELEMBAPAN PADA HASIL TANAMAN DALAM RUMAH HIJAU TROPIKA DENGAN SISTEM PENYEJUKAN PENGEWAPAN

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APPROVAL

I certify that an Examination Committee has met on 30th July 2009 to conduct the final examination of Diyana binti Jamaludin on her master thesis entitled **"Effect of Temperature and Relative Humidity on Crop Yield in A Tropical Greenhouse with Evaporative Cooling System"** in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the student be awarded the (Name of relevant degree).

Members of the Examination Committee were as follows:

Prof. Ir. Dr. Wan Ishak b. Wan Ismail
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Prof. Ir. Dr. Lee Teang Shui
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Associate Prof. Ir. Dr. Azmi b. Dato' Yahya
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Dr. Mohammud Che Hussain
Malaysian Agriculture Research and
Development Institute (MARDI)
(External Examiner)

_____
BUJANG KIM HUAT, PhD
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

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

Desa bin Ahmad, PhD, P.Eng
Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Hawa ZE binti Jaafar, PhD
Associate Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Member)

Rezuwan bin Kamaruddin, PhD
Deputy Director
Malaysian Agriculture Research and Development Institute (MARDI)
(Member)

Mohd. Amin bin Mohd. Soom,PhD, P.Eng
Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

HASANAH MOHD GHAZALI, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 10 December 2009

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 University Putra Malaysia or at any other institution.

_____

DIYANA BINTI JAMALUDIN

Date: 5 January 2010

LIST OF TABLES

Table		Page
1:	Greenhouse area in different countries	9
2:	Yields of some crops grown under the naturally ventilated tropical crop protection structures using hydroponics and fertigation systems	17
3:	Recommended air exchange rate	31
4:	Elevation factor, F_{elev} (above sea level) in m	32
5:	Light intensity factor, F_{light} in Wm^{-2}	32
6:	Pad-to-fan temperature rise factor, F_{temp} in ˚C	32
7:	Pad-to-fan distance factor, F_{vel} in m	32
8:	Pad types with airflow rate specifications	34
9:	Sensors specifications	39
10:	Fertilizer stocks solution in 100 L tank	44
11:	Area segment and representation	45
12:	Row segments and representation	46
13:	Sensors location in Cartesians at horizontal direction of 1st arrangement	50
14:	Sensors location in Cartesians at vertical direction of 1st arrangement	51
15:	Sensors location in Cartesean at horizontal direction of 2nd arrangement	53
16:	Fans pair selection	55
17:	Symbols and description of crop sections inside the greenhouse	56
18:	Elements in the model with value and source	63
19:	Existing and required values for pad-and-fan cooling system for a $300m^2$	64
20:	Distribution and ANOVA for inside temperature between areas in the greenhouse	66
21:	Distribution and ANOVA for inside temperature between rows in the greenhouse	66
22:	Distribution and ANOVA for inside temperature between sensors in vertical direction	69
23:	Distribution and ANOVA for inside relative humidity between areas in the greenhouse	79

24: Distribution and ANOVA for inside relative humidity between rows in the greenhouse 79
25: ANOVA statistical test for inside temperature factors 93
26: PHstat Best Subset Analysis 93
27: Distribution and ANOVA for cabbage canopy diameter between sections 103
28: Distribution and ANOVA for cauliflower canopy diameter between sections 103
29: Distribution and ANOVA for cabbage head diameter between sections 108
30: Distribution and ANOVA for cauliflower head diameter between sections 108
31: Distribution and ANOVA for cabbage head weight between sections 112
32: Distribution and ANOVA for cauliflower head weight between sections 112
33: t-Test analysis for inside temperature in empty greenhouse 115
34: t-Test analysis for inside temperature in greenhouse with crops 118
35: Information needed for spreadsheet 120
36: Information calculated in spreadsheet 121
37: ANOVA for temperature inside the greenhouse between sensors 124
38: ANOVA for relative humidity inside the greenhouse between sensors 125
39 : Cabbage yield in decreasing order for each area and row 126
40: Cauliflower yield in decreasing order for each area and row 127
41: Result of ANOVA for sections in the greenhouse 127

LIST OF FIGURES

Figure		Page
1:	Greenhouse energy balance	19
2:	Experimental greenhouse	27
3:	Evaporative pad constructed at the South-wall of the greenhouse	29
4:	Exhaust fans placed at the opposite North-wall of the greenhouse	29
5:	(a) WatchDog 2000 series weather station (b) LCD screen	38
6:	Solarimeter	38
7:	WatchDog 200 series data logger	39
8:	Germination trays sown with cabbage and cauliflowers seeds	41
9:	Filling up cocoa peat into the polybags	41
10:	(a) Fertilization system; (b) Drip irrigation with microtube	43
11:	Fertilization control system	44
12:	Crop arrangement and sections in the greenhouse	46
13:	Double rows of polybags inside the greenhouse	47
14:	Weather station outside the greenhouse	49
15:	Location of sensors with 1st arrangement	49
16:	Greenhouse floor plan for 1st arrangement of sensors in a horizontal direction	50
17:	Greenhouse side plan for 1st arrangement of sensors in a vertical direction	51
18:	Greenhouse floor plan for 2nd arrangement of sensors in a horizontal direction	53
19:	Location of exhaust fans	54
20:	Arrangement of crops and sections the greenhouse	55
21:	Cauliflower and cabbage at 75 DAS	56
22:	Design of experiment for crops	58
23:	Heat transfer balance in the greenhouse	60
24 :	Inside temperature versus area	65
25:	Inside temperature versus row	65
26:	Inside temperature versus outside temperature in an empty greenhouse	67
27:	Inside temperature versus outside temperature in the greenhouse with crops	68

28: Changes in the vertical temperature profile with time inside an empty greenhouse 70
29: Changes in the horizontal temperature profile with time inside an empty ghouse 72
30: Average horizontal temperature profile inside an empty greenhouse at 10 am 73
31: Average horizontal temperature profile inside an empty greenhouse at 2 pm 73
32: Average horizontal temperature profile inside a greenhouse with crops at 10 am 76
33: Average horizontal temperature profile inside a greenhouse with crops at 2 pm 76
34: Changes in horizontal temperature profile inside a greenhouse with crops 77
35: Inside relative humidity versus areas inside the greenhouse 78
36: Inside relative humidity versus rows inside the greenhouse 78
37: Inside relative humidity versus outside relative humidity in an empty greenhouse 80
38: Inside relative humidity versus outside relative humidity in greenhouse with crops 81
39: Changes in the vertical inside relative humidity profiles with time in an empty greenhouse 83
40: Average horizontal relative humidity profile inside an empty greenhouse at 10 am 85
41: Average horizontal relative humidity profile inside an empty greenhouse at 2 pm 86
42: Changes in the horizontal relative humidity profiles with time inside an empty greenhouse 86
43: Average horizontal relative humidity profile inside a ghouse with crops at 10 am 89
44: Average horizontal relative humidity profile inside a ghouse with crops at 2 pm 89
45: Changes in the horizontal relative humidity with time inside the greenhouse planted with crops 90
46: Inside temperature versus solar radiation in an empty greenhouse 91
47: Inside temperature versus solar radiation in greenhouse with crops 91
48: Inside temperature versus rainfall in an empty greenhouse 92
49: Inside temperature versus rainfall in the greenhouse with crop 92
50: Average temperature profile inside an empty greenhouse with fans 1&2 operated 95
51: Average temperature profile inside an empty greenhouse with fans 1&3 operated 95
52: Average temperature profile inside an empty greenhouse with fans 1&4 operated 96
53: Average temperature profile inside an empty greenhouse with fans 2&3 operated 96
54: Average temperature profile inside an empty greenhouse with fans 2&4 operated 97
55: Average temperature profile inside an empty greenhouse with fans 3&4 operated 97

56: Crops inside the greenhouse 98
57: Cabbages after harvest 98
58: Canopy diameter versus temperature 100
59: Canopy diameter versus relative humidty 101
60: Cabbage canopy diameter according to area 101
61: Cabbage canopy diameter according to row 101
62: Cauliflower canopy diameter according to area 102
63: Cauliflower canopy diameter according to row 102
64: Head diameter versus temperature 105
65: Head diameter versus relative humidty 105
66: Cabbage head diameter according to area 106
67: Cabbage head diameter according to row 106
68: Cauliflower head diameter according to area 107
69: Cauliflower head diameter according to row 107
70: Head weight versus temperature 110
71: Head weight versus relative humidity 110
72: Cabbage head weight according to area 110
73: Cabbage head weight according to row 111
74: Cauliflower head weight according to area 111
75: Cauliflower head weight according to row 111
76: Calculated and measured inside temperature versus time in an empty greenhouse 114
77: Measured versus calculated temperature in an empty greenhouse 114
78: Calculated and measured inside temperature in greenhouse with crops 117
79: Calculated and measured inside temperature in greenhouse with crops 117
80: Spreadsheet for designing greenhouse pad-and-fan cooling system 122

LIST OF ABBREVIATIONS

A	Area of greenhouse, m^2
A_f	Floor area of greenhouse, m^2
C_p	Specific heat of dry air (1.00), KJ/kg dry air (˚K)
E	The ratio of evapotranspiration to solar radiation
F	A decimal representing the portion of greenhouse space actually in plant production
F_{elev}	Elevation factor
F_{house}	Greenhouse factor
F_{light}	Light intensity factor
F_{temp}	Temperature rise from pad to fan factor
F_{vel}	Pad and fan distance factor
F_{crit}	F-test at critical value
I	Solar intensity on a horizontal surface, Wm^{-2}
L	Length, m
M	Ventilation mass air flow, kgs^{-1}
P_a	Pascals
R^2	Coefficient of determination
T_i	Inside design temperature, ˚C
T_o	Outside ambient temperature, ˚C
T_{odb}	Dry bulb temperature of outside air, °C
T_{idb}	Dry bulb temperature of inside air, °C

T_{owd}	Wet bulb temperature of outside air, °
U	The heat transmission coefficient, $W°C^{-1}m^{-2}$
V	Ventilation rate, m^3s^{-1}
cmm	Air quantity, m^3/min
cfm	Air quantity, ft^3/min
m	meter
v	Specific volume of air, evaluated for inside conditions with exhaust fans and outside conditions with pressure systems, m^3/kg dry air
τ	Transmittance of the greenhouse glazing to solar radiation (%)
ρ	Air density kg m^{-3}
ŋ	Pad efficiency (%)
W	Width, m
%	Percentage
Ø	Diameter, m
CAP	Cabbage-Row A- Pad Area
CAM	Cabbage-Row A- Middle Area
CAF	Cabbage-Row A- Fan Area
CBP	Cabbage-Row B- Pad Area
CBM	Cabbage-Row B- Middle Area
CBF	Cabbage-Row B- Fan Area
CCP	Cabbage-Row C- Pad Area
CCM	Cabbage-Row C- Middle Area
CCF	Cabbage-Row C- Fan Area
FAP	Cauliflower-Row A- Pad Area

FAM	Cauliflower-Row A- Middle Area
FAF	Cauliflower-Row A- Fan Area
FBP	Cauliflower-Row B- Pad Area
FBM	Cauliflower-Row B- Middle Area
FBF	Cauliflower-Row B- Fan Area
FCP	Cauliflower-Row C- Pad Area
FCM	Cauliflower-Row C- Middle Area
FCF	Cauliflower-Row C- Fan Area
SA	Sensor A
SB	Sensor B
SC	Sensor C
S1	Sensor 1
S2	Sensor 2
S3	Sensor 3
S4	Sensor 4
S5	Sensor 5
S6	Sensor 6
S7	Sensor 7
S8	Sensor 8
Sout	Outside sensor
BLN	File contains the XY coordinates
BNA	Text document created with Barna
CSV	Comma Separated Value File
DAT	Day After Transplant

ASAE	American Society of American Engineers
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning
LAI	Leaf Area Index
LCD	Liquid Crystal Display
NAR	Net Assimilation Rate
NGMA	National Greenhouse Manufacturing Association
PAR	Photosynthesis Active Radiation
RAM	Random Access Memory
RH	Relative Humidity
TXT	Text / Word file
UV	Ultraviolet
XLS	Excel worksheet file