UNIVERSITI PUTRA MALAYSIA

EFFECT OF EVAPORATIVE COOLING BY MISTING FAN ON MICROCLIMATE OF A NATURALLY VENTILATED GREENHOUSE

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By

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October 2008

Chairman: Desa Bin Ahmad, PhD, P.Eng

Faculty: Engineering

The environment that suits the growth of most kind of crops is very crucial in order to guarantee high quality yields that can be controlled according to the desired parameters and not easily damaged or stunted during its growth. Naturally Ventilated Greenhouse (NVGH) is one of the methods to attain the controlled environment and it is proven to be highly effective in controlling the suitable environment for most kind of plants or vegetables. Furthermore, NVGH can save energy where mechanical, electrical and labour power required is very small, require no controlling procedures or complicated handling, suitable to tropical climate and the cost to build is very low compared to other plant protection structures. The tropical country climate is inconsistent all year long and even though the NVGH can control its environment, it has some weaknesses in which the air and the temperature inside the NVGH can be easily influenced by the outside conditions of the structure. Most kinds of crops require temperature between 20-35ºC and relative air humidity

between 80-90% in order to ensure a standard quality harvest. An evaporative cooling system using four misting fans was studied inside a NVGH of 10m width, 50m long and 4m high. The aim was to modify the environment inside the NVGH so that it could control the inside temperature between 20-35ºC and relative humidity between 80-90% all day long. Other environmental parameters such as light intensity, outside air temperature and carbon dioxide were also studied in order to see the correlation and modification effect on the environment in the NVGH. All environment data studied was recorded and statistically analyzed using the Statistical Package for the Social Science (SPSS) software. Temperature inside the NVGH was found to be strongly correlated with time (min), outside temperature, light intensity and relative air humidity while carbon dioxide only gave a moderate effect on the temperature inside the NVGH. The correlation equation between temperature inside the NVGH is shown in the following equation: $T_1 = -0.001\ (T) + 0.001\ (L) - 0.103\ (H) + 0.447\ (T_2) + 21.949$ where T_1= inside temperature (°C), T= Time (min) L= Light Intensity ($W \cdot m^{-2}$), H=Relative Humidity (%) and T_2= outside temperature (°C). The misting fans also turned out to be effective in controlling the temperature inside the NVGH to remain between 20-35ºC and relative air humidity between 80-90% all day long compared to NVGH that is not equipped with the misting fans. The inside temperature, light intensity and carbon dioxide under the NVGH attached with misting fans were found to be lower than NVGH without misting fans. The relative humidity inside the NVGH attached with misting fans was found to be higher than the NVGH without misting fans. Crop such as chili and cauliflowers were able to grow favourably inside the NVGH attached with the misting fans and the crop growth performance indicates a linear trend during the growing period.

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

KESAN SISTEM PENYEJUKAN PENYEJATAN MENGGUNAKAN KIPAS KABUS TERHADAP PERSEKITARAN DALAMAN RUMAH HIJAU PENGALIHAN UDARA SECARA SEMULAJADI

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Keadaan persekitaran yang sesuai adalah amat penting untuk tumbesaran pelbagai jenis tanaman. Keadaan persekitaran yang sesuai ini dapat menjamin hasil tuaian yang berkualiti, terkawal dalam parameter yang diingini, mencapai target dan tidak rosak atau pun bantut sepanjang tumbesaran. Rumah hijau pengalihan udara secara semulajadi (NVGH) adalah salah satu daripada kaedah untuk mendapatkan persekitaran yang terkawal dan ianya memang terbukti berkesan dalam mengawal persekitaran yang sesuai untuk keperluan tumbesaran tanaman. NVGH ini boleh menjimatkan tenaga dimana kuasa mekanikal, elektrikal dan bilangan buruh yang digunakan adalah kecil, tidak memerlukan prosedur pengawalan dan penjagaan yang rumit, sangat sesuai dengan iklim di negara tropika dan memerlukan kos yang kecil untuk dibina berbanding struktur perlindungan tanaman yang lain. Iklim semulajadi negara tropika secara puratanya adalah tidak konsisten sepanjang tahun dan walaupun NVGH dapat mengawal persekitarannya, ia juga mempunyai kelemahan dimana udara dan suhu didalam struktur mudah dipengaruhi oleh persekitaran diluar struktur

NVGH tersebut. Kebanyakan tanaman memerlukan suhu diantara 20-35ºC dan kelembapan relative udara diantara 80-90% untuk memastikan hasil yang dituai memperolehi standard kualiti yang ditetatpkan. Empat buah kipas kabus (Misting Fan) telah digunakan didalam NVGH yang berkeluasan 10m lebar, 50m panjang dan 4m tinggi untuk mengubahsuaikan persekitaran dalaman struktur tersebut. Ini supaya NVGH dapat mengawal suhu sehingga berada diantara 20-35ºC dan mempuyai kelembapan udara relatif diantara 80-90% sepanjang hari. Beberapa parameter persekitaran yang lain seperti kekerapan cahaya, kandungan karbon dioksida dan suhu udara diluar struktur NVGH juga turut dikaji untuk melihat hubung-kait dan kesan terhadap pengubahsuaian persekitaran didalam NVGH. Semua data-data parameter persekitaran yang dikaji telah direkod dan dianalisis secara statistik dengan menggunakan perisian Statistical Package for the Social Science (SPSS). Suhu didalam NVGH didapati berhubung-kait secara kuat dengan masa (min), suhu luaran, kekerapan cahaya dan kelembapan udara relatif manakala karbon dioksida pula hanya memberi kesan yang sederhana terhadap suhu didalam NVGH. Persamaan hubung-kait diantara suhu didalam NVGH dilengkapi kipas kabus ditunjukkan dengan persamaan ini; T_1= -0.001 (T) +0.001 (L)-0.103 (H) +0.447 (T_2) +21.949 dimana T_1=suhu dalaman (°C), T= masa (min), L= light intensity ($W \cdot m^{-2}$), H= kelembapan udara relatif (%) dan T_2= suhu luaran (°C). Kipas kabus juga didapati telah berjaya mengawal suhu didalam NVGH berada diantara 20-35ºC dan kelembapan udara relatif diantara 80-90% sepanjang hari berbanding struktur NVGH yang tidak dilengkapi kipas kabus. Suhu, kekerapan cahaya dan kandungan karbon dioksida didalam NVGH yang dilengkapi kipas kabus didapati lebih rendah daripada NVGH yang tiada kipas kabus. Kelembapan relatif udara didalam NVGH yang dilengkapi kipas kabus pula didapati lebih tinggi daripada NVGH yang tiada kipas kabus. Tanaman seperti cili

dan kubis bunga pula didapati boleh menbesar secara subur didalam NVGH yang dilengkapi kipas kabus. Ini dapat dilihat melalui graf keupayaan pembesaran bagi cili dan kubis bunga yang menunjukkan trend yang linear sepanjang masa pembesaran tanaman tersebut.

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I certify that an Examination Committee has met on 31 October 2008 to conduct the final examination of Ahmad Syafik Suraidi Bin Sulaiman on his Masters of Science Thesis entitled "Effect of Evaporative Cooling by Misting Fan on Microclimate of a Naturally Ventilated Greenhouse" 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.

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This thesis were submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Master of Science. 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 degree at UPM or other institutions.

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AHMAD SYAFIK SURAIDI BIN SULAIMAN

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CHAPTER 1

INTRODUCTION

The environment-cooling systems design for agriculture requires understanding of the complex interaction between the biological system within the space and the environment provided to that system. The biotic system will have specific environmental needs where its growth, production, and well-being are influenced by the environment. Concomitantly, the biotic system will strongly influence condition within the air space. The aim of the environment cooling is to create a balance favourable to both the biological and physical systems. To be able to create such a balance successfully requires understanding of physics, thermodynamics, mathematics through calculus, fluid mechanics, heat transfer, mass transfer, refrigeration, weather phenomena, control theory and environmental biology.

Greenhouse (crop protection structure) is conventionally used to create environment suiting plant propagation year round, irrespective of external conditions. This may result in conditions outside the human comfort range inside the greenhouse where tropical vegetation is propagated. Greenhouse can have extended action as a non-habitable space to an eventuate gross ventilation by encouraging warm air to vent out of the greenhouse, with replacement air to flow from the abutting building to encourage ventilation there.

The greenhouse is also defined as a special construction which is used to protect plants from undesirable climatic variation and to provide inside environmental conditions to suit the cultivations of plants (Bin Qadhi and Haidrah, 1999). This technique is used to increase the production rate of vegetables, fruits, flowers and to renew plants by using new methods applied to control the surrounding conditions and to produce products at all times of the year.

The naturally ventilated greenhouses (NVGH) rely primarily on the air blowing into a windward side opening and out the open roof vents. Wind can also create a vacuum pressure along the aerodynamically-designed roof vents to accelerate the outward flow of hot air. A secondary, much smaller effect, is the air buoyancy. The air buoyancy helps to move hot, humid air up and out of the greenhouse if there is no internal traps. Nevertheless, any barrier to this process, such as gutter vents or wide internal framing, can completely negate the effect. In all cases, including the open roof designs, it is essential to have at least a very effective windward side inlet with multiple roof outlets. This is to allow the air to move from the inlet to the outlet through the plants to have a good ventilation.

The NVGH has a side netting functions as a cover which its porosity is enough to prevent pest from entering the structures and remove the trapped internal air to the outside of the greenhouse (Figure 1.1).

Figure 1.1: Naturally ventilated greenhouse

The NVGH have low energy requirements where no mechanical or electrical power is used to ventilate the structure. It is also easily cooled in hot climate, has no ventilation restrictions on the length of the greenhouse, the air temperature also can be maintained very close to the outside air, has a very high ventilation rates and has low temperature gradients across the greenhouse area.

The disadvantages of a NVGH include the difficulty in its design. It must be incorporated with some forms of shade system, with no pad cooling and no micro insect screening needed. Besides that, the plants near the side vent can be wind-damaged. This depends on the wind speed and the wind direction. The vents are subjected to wind-damage while the low light plants below the open vents can be sun-scorched.

The NVGH usually has more than one climates. In other words, there are microclimates in a NVGH. These small climates are enclosed in one larger environment. A NVGH frequently becomes too warm when a high level of light intensity occurs. If the high temperatures are to be kept near or below outside ambient temperatures, some form of cooling must be provided. This is important to study the correlation between the light intensity to the temperatures under a NVGH.

Furthermore, numerous applications of environment control in agriculture require more cooling temperatures than what can be provided by the ventilation alone. Temperatures requirement for the best agricultural production typically is within the range of 20 °C to 35 °C. Day temperatures requirement for greenhouse crops is seldom higher than 35 °C. Whenever the outdoor temperature is warm, maintaining the conditions within these ranges can become impossible unless the alternative cooling is used.

The process of cooling off the environment inside the NVGH was done to improve the conditions inside the structure to suit the growth of the crops. Hence, choosing the plant is mainly a matter of knowing what the physiology, chemical and biological aspects needed by the plant. It is important for us to know the kind of light intensity, temperatures, relative humidity and carbon dioxide that each plant requires and how much heat and moisture it needs to thrive. It is also important to choose the crops in order to study the effects of cooling on their growth inside the NVGH.