Application Of Deep Sea Water For Nutrient Cooling System In Hydroponic Culture

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Abstract

Deep Sea Water (DSW) has cold temperature, abundant nutrients, and good water quality that is pathogen-free and stable. Its low temperature is one alternative energy methods for nutrient cooling system in hot season for greenhouse cultivation. Cold DSW pumped inside pipe through cultivation bed might decrease temperature of nutrient solution by heat exchange between nutrient solution and DSW. In this experiment, the heat load of cultivation bed was calculated to evaluate the energy consumption for nutrient cooling system of tomato cultivation in summer. The energy consumption for nutrient cooling system between refrigerator and application of DSW using heat exchanger was compared to evaluate saving energy for all-year-around tomato cultivation. At sunny day, heat load for one nutrient film technique bed along 10 m was 7.4 MJ d^{-1}. In practical cultivation, grower are used to cultivate plants on 80 cultivation beds per 10a area of greenhouse thus, heat load was 590.0 MJ d^{-1} per 10a. When a refrigerator with COP 2.5 is used to maintain nutrient solution at 22 °C, it consumes energy 236.0 MJ d^{-1} or equivalent with 66.1 kW h d^{-1} per 10a while using deep sea water as nutrient cooling system needed energy from 97.2 t d^{-1} DSW + 14.6 kW h of pump. This system only need electrical energy 14.6 kW h of circulation pump thus it could save 78 % of electrical energy consumption than using refrigerator. Growers can save energy and production cost compared to refrigerator that consumed electricity. From environmental perspective, it will reduce electricity consumption that is produced from fossil fuel thus reduce CO_2 emission onto earth. Furthermore it can reduce `greenhouse effect`.

INTRODUCTION

Deep sea water (DSW), accounting for 95% of all sea water, generally refers to sea water from a depth of more than 200 m. DSW has cold temperature, abundant nutrients, and good water quality that is pathogen-free and stable. Currently, the utilization of DSW is receiving much attention due to its high productivity, large quantity, and potential for recycling energy. In Kochi Prefecture, located in Southern Japan, there are a wide range of projects unrelated to fisheries that are utilizing DSW to develop new industries and to contribute to local economies including the food industry, medical treatment facilities, cooling water for power stations and agriculture technique. With low temperature as its characteristic, DSW was used to grow cold climate vegetables, such as spinach, and various cold-season vegetables and crops in the tropics.

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DSW that has low temperature is one alternative energy methods for nutrient cooling system in hot season. Cold DSW pumped inside pipe through cultivation bed might decrease temperature of nutrient solution by heat exchange between nutrient solution and DSW. For environment reason, after being used for cooling system, DSW that contained abundant nutrient can be used as nutrient supplement for tomato plant by diluting into standard nutrient solution. It is suggested that DSW might increase fruit quality because of its enrichment of nutrient solution.

Previous study has shown that deep sea water (DSW) could be used to grow spinach during summer in nutrient film technique (NFT) system (Higa, 2002). Spinach is a vegetable that is used to grow only in winter because spinach grows optimally in low temperature.

In summer, the nutrient solution temperature can reach 35 °C or higher. This temperature is too high for optimum growth. Suhardiyanto (1994) could grow tomatoes in summer and maintained nutrient solution at 22 °C by using refrigerator for nutrient cooling system. It is also reported that root zone cooling system is an energy-efficient cooling system method for NFT system in greenhouse cultivation. The electrical energy consumption during intermittent cooling per floor area was 234.7 kJ m^{-2} d^{-1}. He supposed that it was less than the required energy to cool the entire greenhouse air.

The temperature difference between DSW (13 °C) and nutrient solution (35 °C or higher in summer) could provide energy for cooling system by using heat exchanger. Higa (2002) used DSW to decrease the nutrient solution temperature by using heat exchanger shell-and-tube type. The nutrient solution temperature could be maintained at 22 °C. In this experiment, the heat load of cultivation bed was calculated to evaluate the energy consumption for nutrient cooling system of tomato cultivation in summer. The energy consumption for nutrient cooling system between refrigerator and application of DSW using heat exchanger was compared to evaluate saving energy for all-year-around tomato cultivation.

MATERIALS AND METHODS

In this experiment environmental factor such as air temperature, nutrient temperature solution at the inlet and the outlet of cultivation bed were measured by using wireless LAN system for measurement and recording of environment factors of NFT system. The data were taken and measured every minute using data logger (NEC, DC3100). Data logger was connected to wireless hub to transmit into personal computer (CPU celeron 2.0 GHz, 228 KB RAM) in operator room. Personal computer saved the data every minute. Heat load was calculated using formula :

$$Q = C \rho W (T_1 - T_2)$$

C : specific heat, (kJ kg^{-1} K)
ρ : density of nutrient solution, (kg m^{-3})
T_1 : nutrient solution temperature at the outlet bed, (K)
T_2 : nutrient solution temperature at the inlet bed, (K)

From the heat load of cultivation bed, energy for nutrient cooling system can be evaluated per area cultivation.

RESULTS AND DISCUSSION

Figure 2.1. shows air temperature inside greenhouse, nutrient solution temperature at the inlet and the outlet bed and heat load for 1 bed cultivation. Heat load for one nutrient film technique bed along 10 m was 7.4 MJ d^{-1}. Grower cultivates plants on 80 cultivation beds per 10a area of greenhouse thus in practical cultivation, heat load is 590.0 MJ d^{-1} per 10a. Grower will need a unit cooling system to maintain nutrient solution temperature at optimal degree for plant growth. If a refrigerator with COP 2.5 will be used, it consumes energy 236.0 MJ d^{-1} or equivalent with 66.1 kW h d^{-1} per 10a.

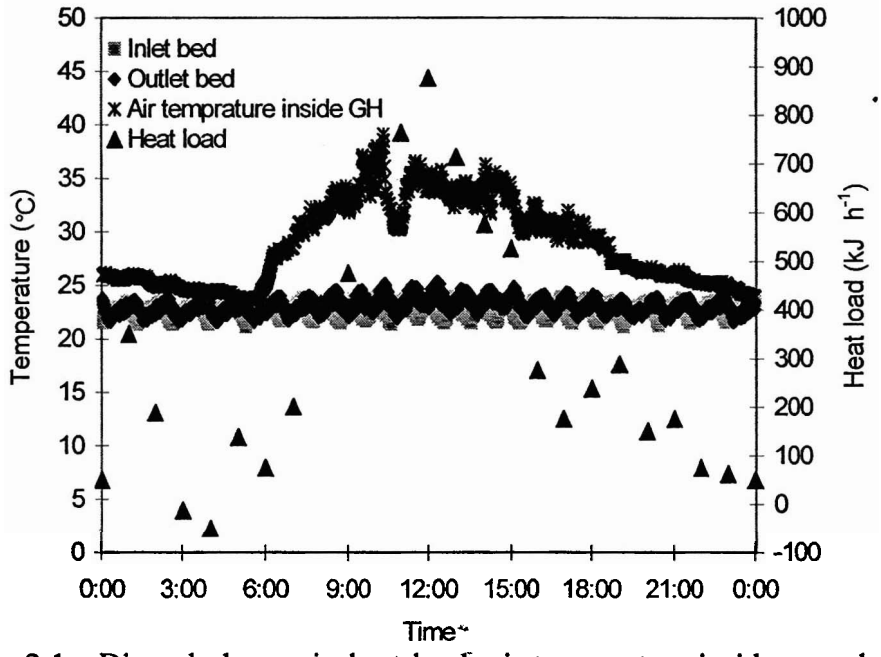

Figure 2.1. Diurnal change in heat load, air temperature inside greenhouse, nutrient solution temperature at the inlet and the outlet of cultivation bed at fine day (July 25, 2003).

According to previous study, maintaining nutrient solution at 22 °C need energy from 97.2 t d^{-1} DSW + 14.6 kW h of pump. This system only need electrical energy 14.6 kW h of circulation pump thus it could save 78 % of electrical energy consumption than using refrigerator.

From grower's perspective, application of DSW for nutrient cooling system has advantageous effect. Tomatoes can be cultivated even in hot weather of summer by using DSW for nutrient cooling system. Thus growers can produce tomatoes all-year-round. Growers can save energy and production cost compared to refrigerator that consumed electricity.

Application of deep sea water for nutrient cooling system can be applied for all-year-round cultivation of vegetables. Air temperature increases during summer especially inside greenhouse. Most of sub-tropic vegetables need low temperature for optimum growing. Growers can provide low temperature in root zone to cultivate the vegetables by applying DSW cooling system. Thus growers can obtain advantage from high price vegetables since there is low supply of vegetables in summer by all-year-round cultivation.

From environmental perspective, it will reduce electricity consumption that is produced from fossil fuel thus reduce CO_2 emission onto earth. Furthermore it can reduce 'greenhouse effect'. After DSW is used for nutrient cooling system, it can be reused for supplementing nutrients in tomato cultivation. DSW is diluted into standard nutrient

solution thus electrical conductivity (EC) of nutrient solution increases. Studies have shown that increasing EC of nutrient solution improved quality parameters of fruit tomatoes.

CONCLUSIONS

It is concluded that application of DSW for nutrient cooling system saved 78 % of kerosene and 78 % of electrical energy consumption when the refrigerator was used. It is more environmental friendly because application of DSW for nutrient cooling system could reduce electrical energy consumption that is produced from fuel fossil thus the emission of pollutant can be reduced too. DSW can be used for nutrient cooling system to cultivate tomatoes in summer for all-year-round cultivation.

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