Research article

The Low-Cost Controlled Temperature Greenhouse Investigation for Marigold Seedlings in Global Warming Situation

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Abstract Global warming situation has affected many life in the world; especially its effects on agricultural industry. Greenhouse was one of many tools which was brought to help farmers in growing many plants and flowers in uncontrollable environments for long time. This work was aimed to build a low-cost controlled temperature greenhouse prototype. The greenhouse prototype was studied for temperature distributions inside the prototype to sow marigold seedlings. A water evaporative cooling system was chosen to remove heat from the greenhouse, a low-cost temperature control set was fabricated to help controlling air flow and temperature inside the greenhouse. A cooling pad system was chosen as the evaporative cooling system in this work. The greenhouse frame was built locally as a length of 2.1 m., a width of 1.8 m. and a height of 3.1 m. and was covered with clear UV reducing plastic. The cooling pad system consisted of 25-watts ventilating fans with a length of 30 cm, a width of 30 cm, a height of 16 cm and one 60-watt water pump. The low-cost temperature control set was connected with the cooling pad system to turn on and off the fan of the system automatically and to remove the humid air out of the greenhouse. Six different seedling materials; pure peat moss, pure bagasse, bagasse mixed with soil at 1:1 and at 1:0.5 by weight, bagasse mixed with soil and rice-straw biochar at 1:1:0.5 and at 1:0.5:0.5 by weight, were also investigated in the greenhouse. The experimental results showed that using one cooling pad could reduce inside temperature with an average temperature different of 2.5 Celsius while using three cooling pads could reduce inside temperature with an average temperature different of 5 Celsius. The air circulation system also affected the temperature distribution inside the greenhouse and could control the temperature inside the prototype. The seedling material which was prepared from bagasse mixed with soil; at a mixing ratio of 1:0.5 by weight, allowed marigold seedling to grow the most in the same experiment period.

Keywords geenhouse, marigold seedling, cooling pad, evaporative cooling system, heat transfer

INTRODUCTION

Global warming situations affect life on the world such as human, animals and plants. Many plants are able to grow in certain ranges of temperatures. High ambient temperatures have affected on annual plants which can grow from seeds and last for a year. Many researches paid attentions on adjusting temperatures to suit seedlings and growing of plants. One of many tools to control suitable temperatures for seedlings and growing of plants was a greenhouse; where sunlight can go through a structure of the greenhouse, humidity and temperature inside the greenhouse can be adjusted by heating, ventilation and air conditioning systems.

Marigold is one of many flowers in Thailand which is used in many occasions such as celebrating for our beloved King Rama 9, worshipping in Buddhist traditions, etc. Varied ambient temperatures also affect seedling and growing rates of marigold because Marigold growing in Thailand prefers surrounding temperatures between 14.5 to 28.6 Celsius (Wongput 2001), quite low temperatures compared with global-warming ambient temperatures in Thailand. Taylor et al. (2013) grew 14-day-old marigold (Tagetes erecta L. 'Inca Gold') seedlings on a greenhouse bench to document the occurrence of nitrification in Pine tree substrate (PTS) and to determine if nitrification and density of nitrifying microorganisms were affected by substrate storage time and lime and peat amendments. Bridgen (2015) proposed UV-C light treatments as a plant growth regulator in seedlings of annual plants such as African marigold and French marigold. He claimed that the use of UV-C irradiation as the novel low-cost technique could provide tremendous benefits for the environment by reducing pesticide applications to plants. Randall and Lopez (2015) also studied and compared seedlings; vinca, impatiens, geranium, petunia, and French marigold, grown under low greenhouse ambient light (AL) to those grown under supplemental lighting (SL) or sole-source photosynthetic lighting (SSL) with a similar photosynthetic daily light integral (DLI). They found that height of marigold was 7% to 19% shorter, for seedlings grown under SSL compared with those under AL and SL. Pramuanjaroenkij et al. (2015) studied fluid flow in Red Oak hydroponics systems to create 4 prototypes of the hydroponics systems inside a greenhouse for a household application with initial conditions as low investment cost and easy installation. Olberg and Lopez (2016) found that all plants were delayed when grown outdoors compared with in the high tunnel, and all marigolds grown outdoors died in April of the Midwestern United States when outdoor air temperatures dropped below −4 °C, growers must be aware of the risk of crop loss due to extreme temperatures and plan for delays when growing annual bedding plant crops outdoors. Pramuanjaroenkij et al. (2017) studied the turbulent flow of the nutrient solution which affected the growth of Red Oaks in four hydroponic systems inside a greenhouse; the greenhouse was proved to help adjusting the temperatures inside the greenhouse. Owen et al. (2017) revealed that the overall trends indicated in most cases as the percent PWC increases, pH increases and electrical conductivity (EC) decreases while plant shoot growth was often as large in fresh PWC-grown plants compared to aged.

OBJECTIVE

This work was aimed to build a low-cost controlled temperature greenhouse prototype to control temperatures to sow marigold seedlings. The greenhouse prototype was constructed locally and experimentally investigated for temperature distributions inside the prototype to sow marigold seedlings. We also investigated suitable marigold for six different seedling materials in the greenhouse with high humidity air because of evaporated water from the cooling pad system.

METHODOLOGY

(1)A greenhouse structure was designed and locally built. (2) A clear UV reducing plastic sheet was cut and covered the greenhouse structure. (3) Temperatures of the greenhouse and environment were measured by an infrared temperature measurement camera to find natural temperature distributions. (4) A temperature control set was fabricated by connecting a thermocouple, a temperature controller and a relay. The relay was used to switch on and off two ventilating fan; one fan was equipped on the top part of the greenhouse to reject the heat and moisture to the environment and another fan was installed opposite to a cooling pad set. (5) Two sets of cooling pads were installed and compared. The first set contained one cooling pad and another set contained three cooling pads. (6) Twenty-three marigold seeds were put into six different seedling materials mixing ratios by weight: pure peat moss, pure bagasse, bagasse mixed with soil at of 1:1

and 1:0.5 by weight, bagasse mixed with soil and rice-straw biochar at mixing ratios of 1:1:0.5 and 1:0.5:0.5 by weight. And (7) Three seedling investigations were studied in three consecutive periods (14 days per period) to conclude the current study. Germination rates of marigold seedlings from these materials were obtained and compared while temperatures inside and outside the greenhouse were measure 3 times a day; 9am, 12.45pm and 7pm.

RESULTS AND DISCUSSION

A greenhouse was locally built as a length of 2.1 m., a width of 1.8 m. and a height of 3.1 m. and was covered with clear UV reducing plastic. The self-built greenhouse was placed in the environment, the temperatures of the greenhouse and environment were measured by an infrared temperature measurement camera to find natural temperature distributions. At the beginning, one cooling pad set was installed and the first temperature distribution was observed as shown in Fig. 1 that high temperature humid air was accumulated on the top of the greenhouse and opposite of the cooling pad. The temperature control set (Fig. 2) was linked with both fans inside the greenhouse and the thermocouple was positioned in the middle of the greenhouse to measure inside temperatures; if the measured temperatures were higher than our set value or 25 Celsius, both fans were switched on and off when the measured temperatures were lower than the set value. To reduce temperatures inside the greenhouse, one cooling pad and three cooling pads were connected with the cooling system and compared, we found that the more pads the lower temperatures, as well as, the higher humidity. High humidity could cause fungi to grow inside the greenhouse; as we avoided too high humidity, three pad were kept as the maximum number. Six different seedling materials were prepared and 23 marigold seeds were put into six seedling materials; 15 holes for each material. Three experiments were carried on consequently, 14 days for each experiment. During each experiment, temperatures and humidity of humid air both outside and inside the greenhouse were measured three times a day; minimum and maximum different temperatures and relative humidity percentage of humid air both outside and inside the greenhouse were detailed in Table 1 according to measuring times during three months in 2017. We noticed that the highest temperature and humidity were in April 2017, the middle month in Summer of Thailand.

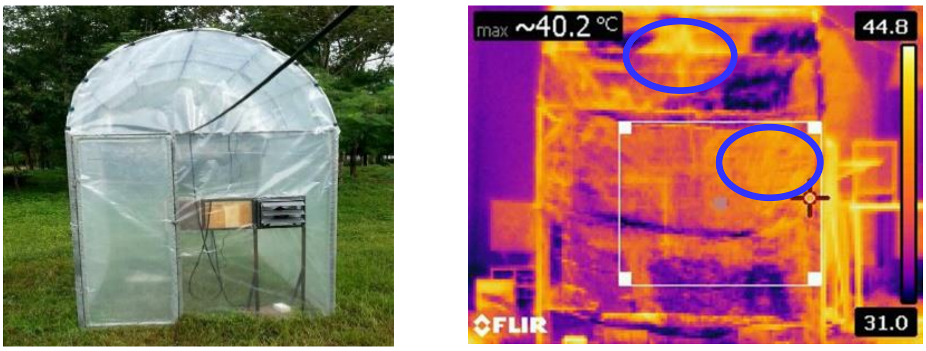


Fig. 1 The greenhouse and temperature distributions

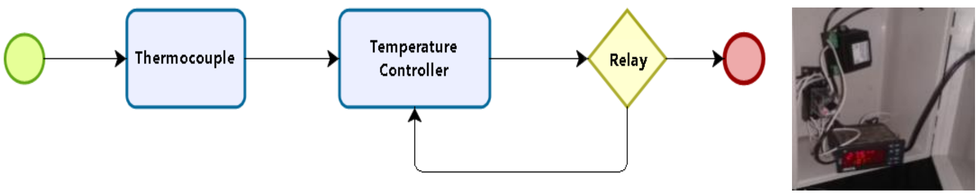
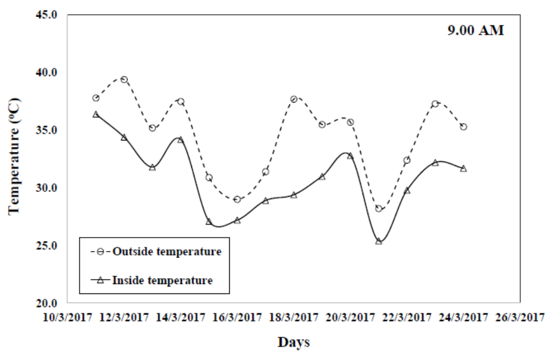


Fig. 2 The temperature control set

Table 1 Minimum and maximum different temperatures (Celsius) and relative humidity percentage (%RH) of humid air both outside and inside the greenhouse

	9 am				12.45 pm				7 pm			
	ΔT_{min}	ΔT_{max}	$\Delta\%RH_{min}$	$\Delta\%RH_{max}$	ΔT_{min}	ΔT_{max}	$\Delta\%RH_{min}$	$\Delta\%RH_{max}$	ΔT_{min}	ΔT_{max}	$\Delta\%RH_{min}$	$\Delta\%RH_{max}$
1st test	1.4°C on Mar. 11th	8.3°C on Mar. 18th	1 on Mar. 17th	14 on Mar. 12th	1.1°C on Mar. 19th	7.9°C on Mar. 16th	1 on Mar. 20th	19 on Mar. 13th	1°C on Mar. 12th	4.9°C on Mar. 22nd	1 on Mar. 12th	22 on Mar. 23th
2nd test	2.4°C on Mar. 29th	8.8°C on Apr. 4th	0 on Mar. 31th	48 on Apr. 6th	2.0°C on Mar. 29th	9.9°C on Apr. 5th	7 on Apr. 4th	56 on Apr. 5th	1.6°C on Mar. 29th	5.8°C on Apr. 9th	5 on Mar. 31th	60 on Apr. 9th
3rd test	0.5°C on May 13th	8.4°C on May 6th	4 on May 12th	28 on May 2nd	2.1°C on May 7th	7.4°C on May 5th	1 on May 13th	24 on May 6th	3.3°C on May 3rd,4th	5.3°C on May 2nd	3 on May 6th	42 on Apr. 30th

Figures 3, 4 and 5 showed average outside and inside temperatures of the greenhouse in March, April and May, respectively. We found that the average inside temperature of the greenhouse in the morning (9am) in May was the lowest inside temperature among temperatures in three experimental periods, the inside temperatures varied from 23 to 35 Celsius, the lowest and highest average different temperatures between outside and inside greenhouse was about 1.4 Celsius and 8.3 Celsius, respectively. The average inside temperature of the greenhouse at noon (12.40pm) in March was the highest inside temperature among temperatures in three experimental periods, the inside temperatures varied from 29 to 38 Celsius, the lowest and highest average different temperatures between outside and inside greenhouse was about 1.1 Celsius and 7.9 Celsius, respectively.



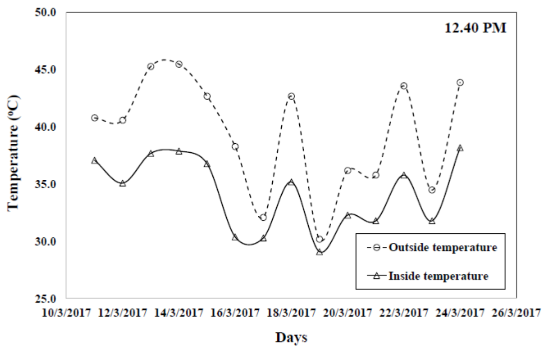


Fig. 3 The outside and inside temperature of the greenhouse in March

We noted that our greenhouse, which was cooled by evaporative refrigeration, contained high relative humidity. Seedling materials, which was suitable inside this specific greenhouse, must function well in the high humidity atmosphere. Among three different experimental periods, the first set of seedlings in any seedling materials, which were placed inside the greenhouse, could germinate out of their seedling materials in the same day on the fourth day of marigolds planting. The highest amount of seedlings germinated out from the bagasse mixed with soil at mixing ratios of 1:0.5 by weight. The bagasse mixed with soil at mixing ratios of 1:0.5 by weight showed its potential in growing marigold seedlings inside the greenhouse while the marigold seedlings in different seedling materials, which were placed outside the greenhouse, were damaged by pest animals and less seedlings could germinate out of the materials than those of the materials inside the greenhouse. Therefore, the bagasse mixed with soil at mixing ratios of 1:0.5 by weight greenhouse could be applied as the seedling material which suited to the high humidity atmosphere occurred by the evaporative refrigeration. Another greenhouse utilization found in this study was the greenhouse could protect seedlings, plants and their seedling materials from pest animal damages.

We summarized costs of the greenhouse structure, plastic cover, simple temperature control set and three cooling pad set including a water circulating pump, and we found the cost of our greenhouse at $4 per square meter. From our survey, the estimating cost of the greenhouse building in US was $55.56 per square meter (HomeAdvisor, Inc. 2017) or $19.45 per square meter as we estimated Thai construction cost at 65% lower than the American construction cost (Neal and Rawlinson 2014). The cost of the current greenhouse installed with the cooling pad and temperature control sets or $4 per square meter was lower than the estimated greenhouse cost or $19.45 per square meter about 79%.

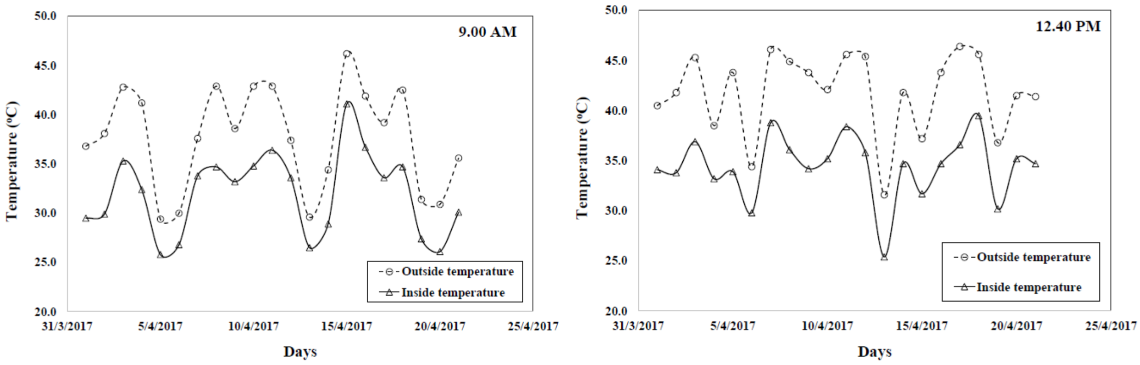


Fig. 4 The outside and inside temperature of the greenhouse in April

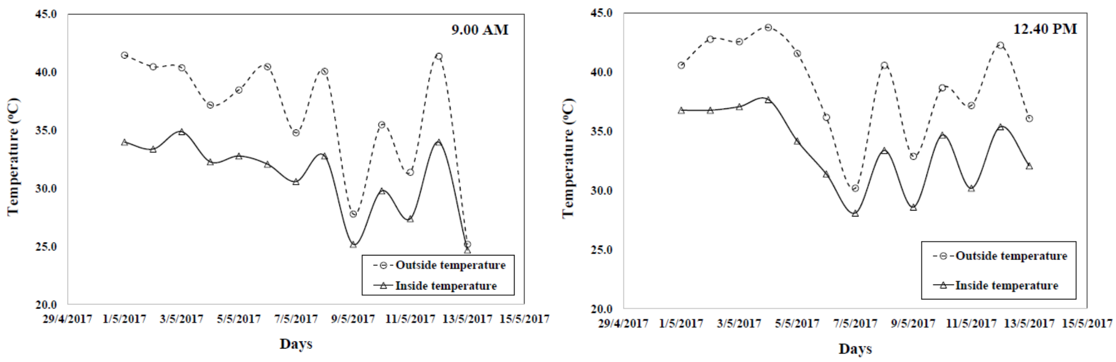


Fig. 5 The outside and inside temperature of the greenhouse in May

CONCLUSION

This study was aimed to study and develop a closed controlled greenhouse. Evaporative cooling system was chosen as the greenhouse cooling system. The evaporative cooling system consisted of cooling pads (where water was circulated and received heat from the greenhouse), water pumps (which were used to circulate the water) and ventilation fans (one fan was placed near the cooling pad to draft inside air to pass the cooling pads and another fan was placed at the top of the greenhouse roof to release hot air out of the greenhouse). The temperature control set could control operation of the evaporative cooling system and the system could reduce inside greenhouse temperatures down with an average temperature difference (between inside and outside greenhouse temperatures) of 5 Celsius. There were six different seedling materials which were investigated, 23 marigold seeds were put into these six different seedling materials in each experiment period; 15 seedling holes for each material. Six different seedling materials were prepared from 1) peat moss, 2) bagasse mixed with soil at mixing ratios of 1:1 by weight, 3) bagasse mixed with soil at mixing ratios of 1:0.5 by weight, 4) bagasse mixed with soil and rice-straw biochar at mixing ratios of 1:1:0.5 by weight, 5) bagasse mixed with soil and rice-straw biochar at mixing ratios of 1:0.5:0.5 by weight and 6) only bagasse. The air circulation system also affected the temperature distribution inside the greenhouse and could control the temperature inside the greenhouse. The seedling material which was prepared from bagasse mixed with soil; at a mixing ratio of 1:0.5 by weight, allowed marigold seedling to grow the most in the same experiment period. Marigold seedling germinated the first set in every seedling material at the same day (the fourth day of the planting periods). The greenhouse could also protect the Marigold sprouts from pest animals because the sprouts grown outside the greenhouse were damaged by pest animals. The bagasse mixed with soil; at a mixing ratio of 1:0.5 by weight as the marigold seedling material revealed its function and potential in the high humidity atmosphere because the evaporative cooling system, which applied cooling pads, generated a lot of water vapor causing high humidity atmosphere. The construction cost of the current designed greenhouse was $4 per square meter which was an affordable cost for farmers, the current greenhouse with the temperature control set was suitable as a household greenhouse, simple in design and construction as well as easy to maintenance and develop to sustain the greenhouse application in the rural area.

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