ABE

Agricultural and Biological Engineering

https://ph04.tci-thaijo.org/index.php/abe/index

Published by the Faculty of Engineering, Khon Kaen University, Thailand

Development of suitable greenhouse to increase melon production efficiency

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Received 29 July 2024
Accepted 12 October 2024

Abstract

This research aims to develop a greenhouse, which suitable for increasing melon production efficiency by developing ventilation of the new greenhouse to be better than the primitive greenhouse; semi-circular greenhouse (farmer's greenhouse). The new greenhouse has overlap curve roof with overhead opening is designed for cooling down temperature in the greenhouse. Temperature and relative humidity in the greenhouse are controlled close to the outside by a control system and the automatic fan activated when the temperature reaches 40 °C. The greenhouse is, 30.0 m. long ,6 m. wide, 3.0 m. high of pole and 1.5 m high of roof. The structure is galvanized steel pipe. The roof is covered with plastic 150 microns thick, the 32-mesh net used for the side walls. The construction costs less than 100,000 THB per unit, exclude fertilizer, irrigation systems, automatic temperature and humidity control systems along with ventilation fan set. The temperature measurement in the new greenhouses shown that the temperature decreases 5 - 15 °C when the inside air is ventilated by fan system, moreover in a sunny day that temperature reaches 40 °C, the automatic fan system reduces temperature to 37 °C. The melon variety used in this experiment is the Morakot variety, which is a popular melon variety consumed in Thailand. In terms of productivity, it was found that the greenhouse had an average total yield of 512 kg, an average income of 26,327 THB and a net profit of 6,633.21 THB per production cycle. Meanwhile, the farmer's greenhouse has an average total yield of 476 kg, an average income of 24,720 THB and a net profit of 2,692.88 THB per production cycle. The sweetness of the melon form both types of greenhouses pass the standard. The greenhouse has an economic break-even point of 3.36 years with the lifetime of 10 years, while the farmer's greenhouse has the break-even point of 3.21 years with the lifetime of 5 years.

Keywords: Greenhouse, Melon, Production efficiency

1. Introduction

Melon (Cucumis melo L.) is a plant that in the past had to be imported from abroad. Therefore, it is quite expensive. But at present, Thailand has developed the ability to grow melon itself. Consequently, it is widely consumed. As a result, melon is more well known. Because it has good flavor, soft flesh, sweet, juicy and fragrant aroma. The flesh has a variety of colors, including white, cream, yellow, green, orange and red, making it more appealing to eat. Classified as both fruits and vegetables depending on the nature of consumption. which are both consumed fresh in the form of fruit or use it as an ingredient in salads. It is also used to make many desserts and drinks, such as fruit salad, ice cream, shaved ice, and fruit smoothies, etc., which are suitable for consumption during hot weather. The current demand for melon consumption is increasing, Accordingly, makes it become the economical crop with the best price among the cucumber family plants, and is in demand in the market. It is also a plant that takes a short time to grow and harvest compared to other fruits. Some varieties have a harvest time of no more than 65 days after sowing seeds. Therefore, it is classified as a crop that generates income for farmers. Although melon is a plant with high potential in the market, Thai farmers still lack of high experience, as well as advice and technology for producing melons to meet market demand [1].

For the varieties grown in Thailand and sold in the market, they are well-known and can adapt to the environment of Thailand, such as the Morakot variety, which is a Japanese melon with a round fruit shape, a netted skin, green, soft flesh, sweet taste and fragrant smell. It weighs 1-1.8 kilograms per fruit, depending on the health of the tree. It is popularly grown in the central, western and eastern regions because it is easy to grow and bear fruit, can be harvested quickly, and is resistant to hot weather. Farmers can grow it as a main crop or as a supplementary crop for income. If the produce is of good quality, it will be very expensive. Most of the planting areas

are in the central river basins of the country, in the provinces of Lopburi, Singburi, Saraburi, Phra Nakhon Si Ayutthaya and Nakhon Ratchasima. In 2006, Thailand had a total melon production of 16,624.45 tons [1].

Currently, melon cultivation is still limited. Because it is planted outdoors, the yield will not be full and it can only be planted during the dry season or after rice fields. In addition, it is easily damaged by diseases and insects. Therefore, many farmers bring it to grow in greenhouses. Roofing with plastic. The sides are covered with a 32-mesh net, which allows for good cultivation. But still unable to adjust appropriately to the environment. This is because the design of farmers' greenhouses is not yet appropriate. Lack of ventilation system, drains moisture and there is no temperature control system. As a result, the production is not at full capacity. Because Thailand is geographically located in the tropics or the equator, greenhouse design must be well adapted to local conditions in order to achieve high yields. Good greenhouse requirement should be able to control the sun light, protect from rain and circulate the air inside. These keep the temperature in the greenhouse from being too cold or too hot. Helps to grow all year long. Reduce the spread of leaf disease outbreaks. How to grow melons in a greenhouse: They can be planted in the ground or in growing media in containers or pots. Planting in pots has the advantage of being able to use a closer planting distance than planting in the ground and this method also allows for continuous planting in successive seasons, because it reduces the spread of soil-borne diseases [3].

Suitable environmental conditions for growing melons should be planted in sandy loam soil which has good water draining. Melon is a plant that does not like waterlogging. The optimum pH is between 6.5 – 7.0 or neutral soil conditions. The ideal weather condition is warm with sufficient sunlight, the average temperature is around 25 - 35 °C, not exceeding 40 °C, and the relative humidity is 50 - 70%. Needs regularly watering during the growth of the stems and leaves, at the melon's fruiting stage less water is need. The melons will grow and produce well during the summer and grow slower during the winter [2].

To solve this problem, it is necessary to develop a greenhouse that can control the environment suitable for melon production so that it can be grown all year long, in quantity and in high quality, safe for consumers. As a result, the value per unit of output increases. Farmers income will increase.

Research objective is to develop greenhouses that suitable for growing melons by intergrading sensor systems to measure temperature and humidity automatically and setting a cooling system inside the greenhouse, using fans to ventilate the heat through the roof.

2. Materials and methods

2.1 Equipment

Greenhouse structural consist of various sizes of steel such as galvanized steel pipe, black steel sheet, box steel, 150-micron plastic used as the roof, 32 mesh netting is covered around the sides of the greenhouse and attached the net with spring rails and spring locks, The water system including, PE pipe, PVC pipe, water pump, pump controller set, mist spryer nozzle, Venturi fertilizer set. Sensor as temperature, humidity and light are set as well as data logger which used for collecting the greenhouse data. In the section of planting, Emerald melon seeds, chemical and fertilizer for soils, plant hormones, plant disease control, chemicals insecticide chemicals are prepared. Finally, refractometer for measuring of melon sweetness is used.

2.2 Methods

2.2.1 Greenhouse construction

1) Choosing a greenhouse model, we studied the greenhouses currently used by farmers that have a semi-circular roof. There is no cooling mechanism above. Farmers still don't have greenhouses that are well ventilated. Regarding to The Agricultural Engineering Research Institute who has been conducting research on greenhouses for growing plants, it was found that the semi-circular overlapping greenhouses were able to ventilate heat well. Therefore, a greenhouse with a semi-circular overlapping roof was chosen as a prototype. Because the roof has an opening, makes it easier to vent the inside hot air, suitable for tropical countries. The advantage and disadvantage of the new greenhouse (prototype) will be compared to the farmer greenhouse type.

2) Select the greenhouse currently used by farmers; semi-circular roof design, 6 x 30 m of dimension, 3 m high of pillars, 1.5 m additional for roof height, this model will be used for comparison.

Prototype greenhouse design, the structure of the house is made from 1-inch galvanized steel pipe, curved at the top to form a semi-circle but with an overlapping distance of 0.5 m allowing warm air ventilate to the top. The side pillars are made from galvanized steel pipe, 2.0 m high, 2 inches wide. At the base, the pillars are cast in cement, width 0.2 m, embedded 0.5m deep. The greenhouse has dimensions of width 6.0 m, length 30.0 m, pillar height 2.0 m, roof height 1.5 m, total height 3.5m, designed to have a construction cost of no more than 100,000 THB per building. Does not include fertilizing, watering, automatic control systems (temperature, humidity), ventilation fan sets. The roof is covered with plastic. and the sides are lined with 32-mesh netting as shown in Figure 1. It is a prototype half-circle overlapping greenhouse built alongside the farmer's greenhouse is shown in Figure 1.

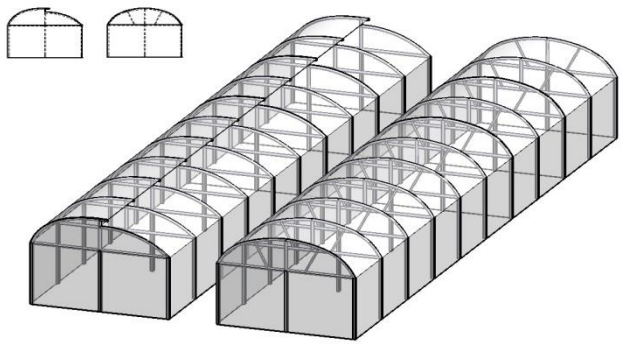

Figure 1 A semi-circular overlapped roof model house (Left) a semi-circular roof farmer's model (Right)

3) Installation of a system to control various plant factors, including temperature sensors. Relative humidity sensor by installing in the middle of the greenhouse. Each unit is 2.0 m high from the ground. The fans are installed 2 units, the first one is installed 5.0 m away from the door to the greenhouse, the second one is installed 15.0 m away from the first one is shown in Figure 2.

Figure 2 Fan installation point (Left) Humidity and temperature sensor with Data Logger (Right)

4) Installing water and fertilizer system in both greenhouses is shown in Figure3.

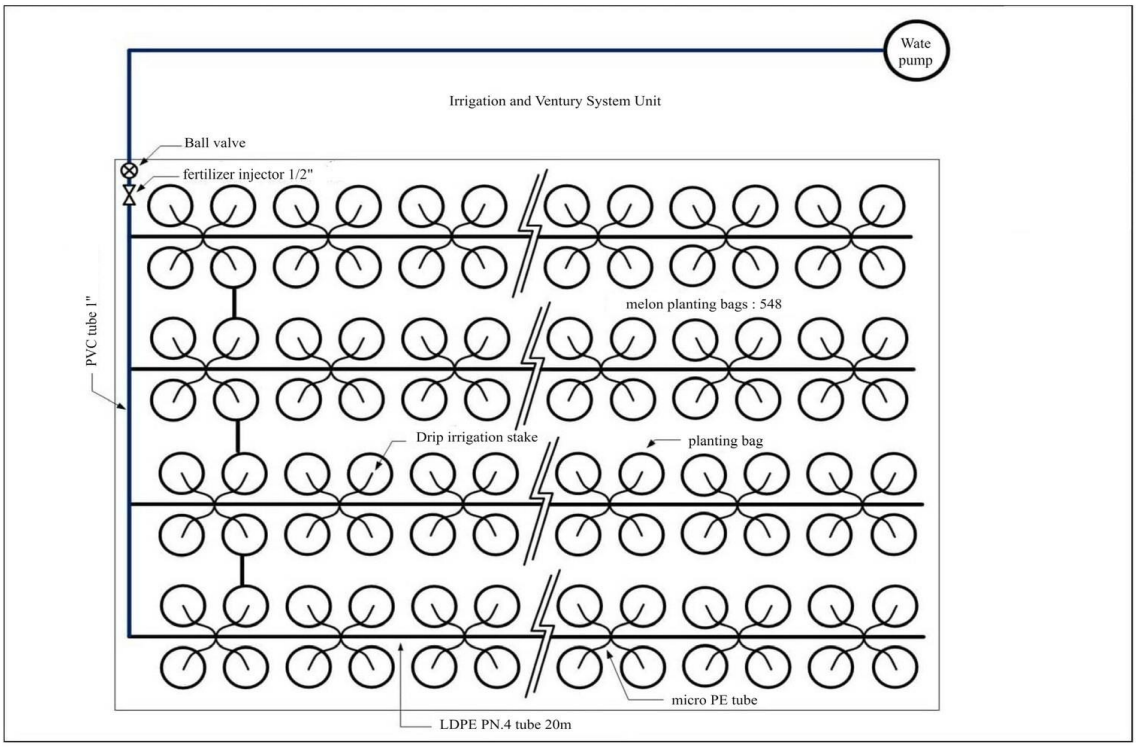

Figure 3 Diagram of watering and fertilizing system installation in a melon greenhouse.

5) The mist spraying nozzles are set to increase the humidity in the two greenhouses is shown in Figure 4.

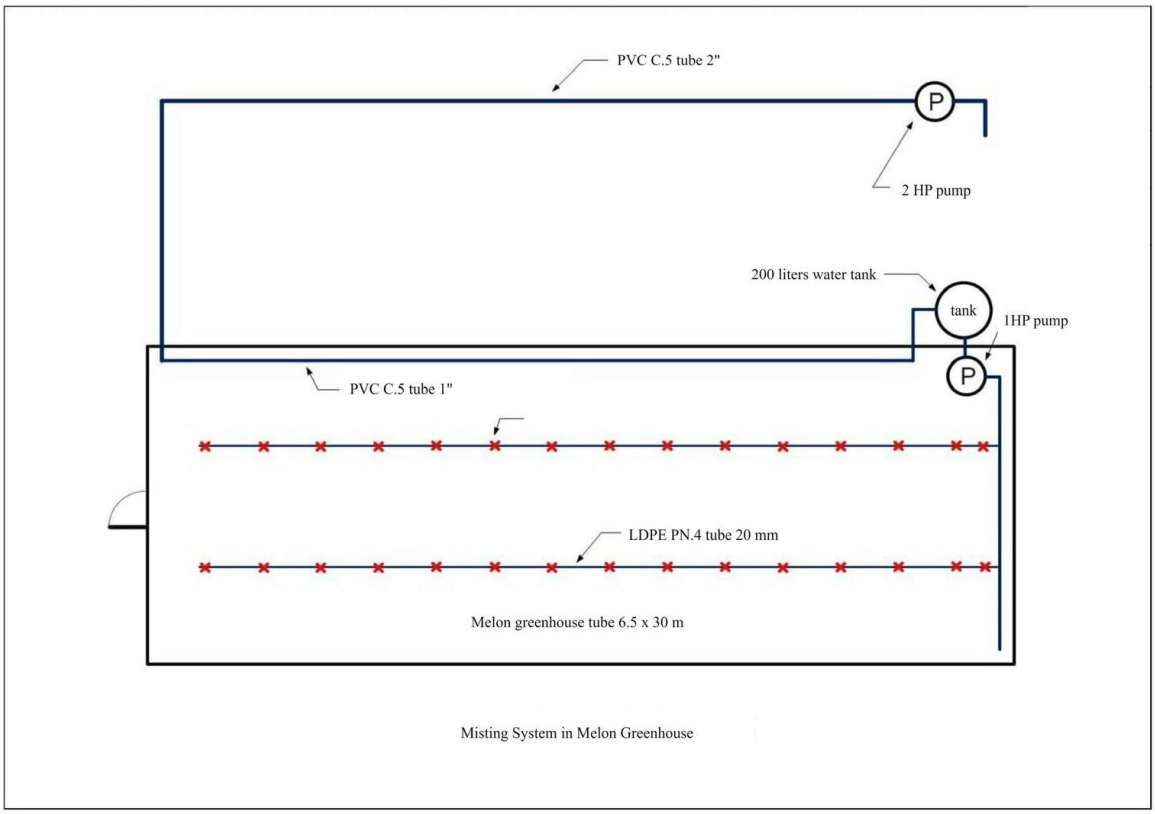

Figure 4 Diagram of misting system installation in a melon greenhouse

6) The cooling fans are installed to reduce temperature in the prototype greenhouse is shown in Figure 5.

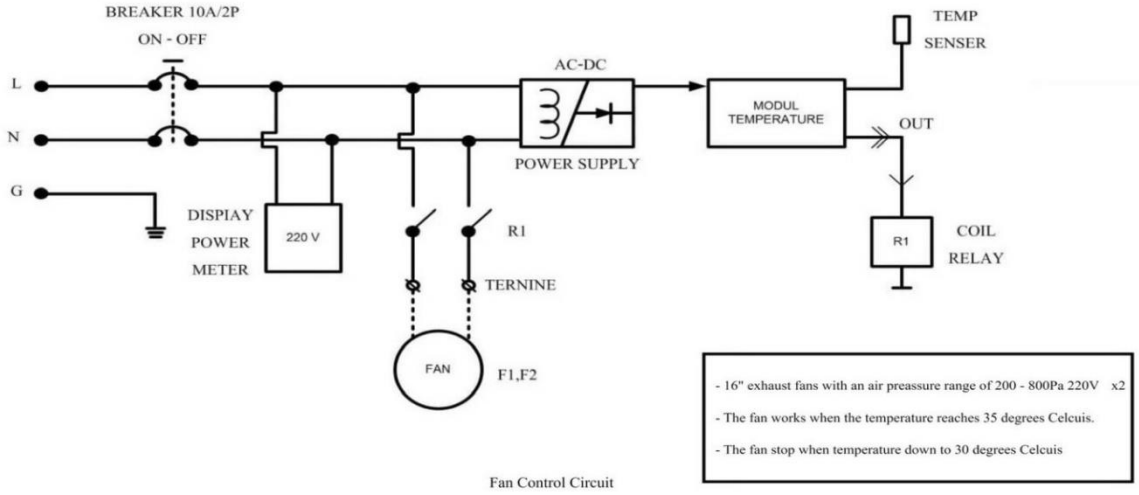

Figure 5 Fan control circuit

2.2.2 *Method of testing in the greenhouse*

Starting with planning the experiment, however statistical experiment design is not used. The comparative test of melon productivity in used to compare the difference of the two types of greenhouses. Including, type 1; a prototype greenhouse (semi-circular roof greenhouse) and type 2; a farmer's greenhouse (semi-circular roof greenhouse), type 2 doesn't equip with ventilation fans.

The greenhouses are built and tested in different province as follow, Khu Mueang District, Buriram Province and Khong District, Nakhon Ratchasima Province. The two types of greenhouses located side by side on farmers' land. Type 1, namely the prototype greenhouses newly developed by the Department of Agriculture and Type 2 for farmer's greenhouse that is currently used by farmers to grow melons. Comparative testing of 4 buildings in two provinces.

Data collection: a mouth of water and fertilizer used are recorded. The melon has 10 grades, every grade is sampling randomly in each greenhouse to measure the sweetness. The weight of each grade is recorded. Temperature and relative humidity are also recorded. Finally, economic data such as costs, selling price, production cost are all recorded.

3. Results and discussion

3.1 Design and construction of prototype greenhouses

A prototype greenhouse has been designed and built, which is a half-round overlapping roof that is easy to ventilate hot air. Research by the Agricultural Engineering Research Institute, Department of Agriculture, has found that the half-round overlapping roof can ventilate heat well, such as the research and development of a greenhouse for cultivating high-quality lady's slipper orchids (*Paphiopedilum*) [5], and in 2021, Sarawut has studied on the research of Development of a prototype greenhouse for off-season lotus production for export [4]. In this research, the semi-circular overlapping greenhouse was chosen as a prototype for developing melon planting. The greenhouse structure is stronger than the greenhouses currently used by farmers. It was built according to civil engineering principles. The prototype was constructed at the Chiang Mai Agricultural Engineering Research Center and then installed in Kong District, Nakhon Ratchasima Province and Khu Mueang District, Buriram Province, as shown in Figure 6.

Figure 6 Construction of prototype greenhouses

The prototype greenhouse that was built has been improved and added many items to make it stronger and has better heat dissipation than the farmer's greenhouse, such as the roof has a heat vent (semi-circular overlapping roof), each pillar has a support made of cement, the steel used for construction is galvanized steel, there is an automatic temperature and humidity control system under the operating conditions. In terms of the fertilizer and watering system, both greenhouses are the same. Using in-bags planting only with planting materials to prevent damage from roundworms, using a mixture of black soil, rice husks, coconut husks (Figure 3), which makes the management of the watering system, fertilizer, pesticides and maintenance easier. Both places of greenhouses are the same is shown in Figure 7.

Figure 7 Planting in a bag and positioning the water system

From collecting temperature and relative humidity data using Data Logger during May - August 2018, which was the period of melon planting in the farmer's greenhouse and the prototype greenhouse of the Department of Agriculture, it was found that the prototype greenhouse, if the fan was not turned on, the hottest temperature between inside and outside the greenhouse was at most 5.0 °c , while the farmer's greenhouse had a maximum temperature difference of 10.0 °c from outside, and the temperature difference between the prototype greenhouse and the farmer's greenhouse was 1.0 – 5.0°c. However, the temperature inside the prototype greenhouse could be reduced by setting the fan to work automatically to help cool down when the temperature reached 40.0 °c and stop working when the temperature dropped to 35.0 °c, with the condition that the temperature outside the greenhouse must not be higher than inside the greenhouse.

3.2 product

When the fruit is ripe and ready to be harvested, the fruit color turns to dark green, the melon net is clearly raised, the fruit calyx is raised or there are longitudinal cracks at the fruit stalk. The age after pollination is counted to be between 43 - 45 days. Use human labor to collect from the greenhouse and then weigh the fruits using human labor on grading process, including grades A, B, and C as shown in Figure 8.

Figure 8 Melons ready for harvest (Left), Weighing for grading process (Right)

Melon planting crop number 1, Kong District, Nakhon Ratchasima Province Started planting on 2nd January 2018, harvested on 15th March 2018. Crop number 2 of melon planting at Khong District, Nakhon Ratchasima Province, planted on 2nd May 2018, harvested on 16th July 2018.

First crop of melon planting in Khu Mueang District. Buriram Province, planting on 2nd March 2018, harvesting on 16th May 2018, the second crop of melon planting in Khu Mueang District, Buriram Province, planted on 5th June 2018, harvested on 20th August 2018 (production data shown in Table 1)

Table 1 Grading output Total production and net income of melon cultivation in a prototype greenhouse and farmer's greenhouse in Kong district Nakhon Ratchasima Province and Khu Mueang District Buriram Province

Location	Greenhouse type	Grade (kg./Greenhouse)				Total	Summary of net
		A	B	C	rotten	(kg./ Greenhouse)	income (bath/kg.)
Nakhon Ratchasima 15th Mar 2018	Greenhouse Prototype	451	55	25		531	29,610.-
	Greenhouse Farmer's	420	62	21		503	27,895.-
16th July 2018	Greenhouse Prototype	447	40	62	55*	549	29,770.-
	Greenhouse Farmer's	442	53	20	53*	515	28,875.-
Buriram 16th May 2018	Greenhouse Prototype	194	204	36		434*	19,680.-
	Greenhouse Farmer's	184	212	48		444*	19,660.-
20th August 2018	Greenhouse Prototype	337	103	97	90*	537	26,250.-
	Greenhouse Farmer's	297	93	55	60*	445	22,450.-
Average	Greenhouse Prototype	357	101	55		513	26,327.-
	Greenhouse Farmer's	336	105	36		477	24,720.-

*Product damage from infestation of powdery mildew, thrips, red mites, whitefly

Grade A wholesale price: 60 THB/ kg, retail price 120 THB/ kg

Grade B wholesale price 35 THB/ kg, retail price 80 - 120 THB/ kg

Grade C wholesale price 25 THB/ kg, retail price 36 THB/ kg

Grade A weigh is between 1.80 - 2.50 kg, Grade B weigh is between 1.30 - 1.79 kg, and Grade C weigh is less than 1.30 kg. The total sweetness measured was around 13.0 – 14.0 °C. Brix, which is within the standard range.

From Table 1, it can be seen that the prototype greenhouse has an average total yield of 513 kg, while the farmer's greenhouse has an average total yield of 477 kg. The prototype greenhouse has a yield of more than 36 kg, and the average income from the prototype greenhouse's yield is 26,327 THB per crop cycle, while the farmer's greenhouse has an average income of 24,720 THB per crop cycle. The prototype greenhouse has an average income of more than 1,607 THB. This may be due to the greenhouse temperature, as the prototype greenhouse has a lower temperature during the hottest period of each month than the farmer's greenhouse, for example, the average maximum temperature in June of the farmer's greenhouse is 53.06 °C, while the prototype greenhouse has an average maximum temperature of 44.12 °C, which is a clear difference of 8.94 °C. However, there are many other factors related to the yield, such as disease and insect infestation, the appropriate mixture of planting materials, etc. Therefore, there should be more experiments to confirm the results and tested in different environments such as the northern, central and eastern regions of Thailand.

In terms of economics, it was found that the prototype greenhouse had a net income at 6,865.81 THB per crop cycle, while the farmer's greenhouse had a net income at 2,721.88 THB per crop cycle, the difference is 4,143.93 THB. This wasn't because only the higher production, but the lifespan of the greenhouse was different. The prototype greenhouse was made of galvanized steel pipe, which is resistant to corrosion, and has a solid base, making it last more than 10 years, while the farmer's greenhouse was made of black steel pipe, exposed to the sun and rain, making it last less than 5 years.

4. Conclusions

1. From the design and development of a greenhouse suitable for growing melons, the greenhouse has been developed to have better heat dissipation than the semi-circular (farmer's greenhouse), with an opening for heat dissipation on top. The greenhouse structure is made of galvanized steel pipe. The greenhouse size is 6.0 m wide, 30.0 m long, 3.0 m high of pillars additional with 1.5 m high roof, the area is 180 m^2. It is designed to cost less than 100,000 THB per unit. The roof is covered by 150 - micron thick plastic, and the 32 -mesh netting is used to cover the sides. The prototype greenhouse can control the climate inside, including temperature and relative humidity, hot air ventilation using fans, and uses the principle of a semi-circular overlap, which is that hot air will rise and be flow through the vents on the top, making the temperature inside and outside the greenhouse not very different. The system is automatically controlled by temperature and humidity sensors with fans to ventilate the temperature and reduce humidity inside the greenhouse.

2. The test results of the 2 provinces, Nakhon Ratchasima and Buriram, planted melons by comparing with the farmer's greenhouse (semi-circle type). In terms of temperature, it was found that the different temperature inside and outside the greenhouse was 5.0 °C.

The temperature inside and outside the farmer's greenhouse differed by a maximum of 10.0 °C, and the temperature difference between the prototype greenhouse and the farmer's greenhouse was a maximum of 1.0 – 5.0 °C. However, the prototype greenhouse could reduce the temperature by setting the fan to work automatically when the temperature was high (set at 40.0 °C) and stop working when the temperature dropped (set at 35.0 °C). In terms of relative humidity, when the humidity is lower than 50%, the mist spraying system will work and will stop working when the humidity reaches 70%, which is the appropriate humidity for growing melons. In terms of yield, it was found that the prototype greenhouse produced an average total yield of 513 kg per production cycle. While the farmer's greenhouse has an average total yield at 477 kg. The prototype greenhouse yields more than 36 kg. The prototype greenhouse has an average net income of 26,327 THB per a production cycle, with a net profit of 6,836.10 THB per cycle. While the farmer's greenhouse has an average total yield of 476 kg per one production cycle, with an average net income of 24,720 THB per production cycle, with a net profit of 2,692.88 THB per cycle. It can be seen that the prototype greenhouse has more net profit per cycle than farmer's greenhouse at 4,143.93 THB. When considering only the net income, it can be said that the prototype greenhouse has a net income from growing melons that is higher than the farmer's greenhouse.

The prototype greenhouse has an economic break-even point at 3.35 years, with a lifespan of 10 years, while the farmer's greenhouse has the break-even point at 3.21 years, with a lifespan of 5years. It is clearly shows that the prototype greenhouse has a lifespan of more than 10 years because the galvanized steel structure is durable with rust resistance than the farmer's original greenhouse structure. When calculating the profit per time, it is more than 2.46 times.

3. In addition, with small adjustment to the greenhouse setting as temperature and humidity, other types of plants can be grown. The greenhouse can be distributed to grow other types of plants in all tropical areas.

5. Acknowledgements

Thank you to all the staffs of the Chiang Mai Agricultural Engineering Research Center who dedicated themselves to contribute the success of the greenhouse project.

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