EVALUATION OF METHODS FOR PRODUCING COLD WATER TO COOL GREENHOUSES

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Outline presentation

- Introduction: Why close a greenhouse?
- How to close a greenhouse
- Production of cold water
- Future research

Why close a greenhouse?

- Maintain a high level of CO_2 → Higher production
- Reduce emission (CO_2, pesticides)
- Reduce water use
- Reduce risk of diseases
- Optimal control climate
- Reduce energy use

Economic profit!

How to close the greenhouse?

Aspects to consider:

- Light interception by installation
- Homogeneous climate (horizontal and vertical gradients of temperature and relative humidity should be minimized)
- Capacity of the system (completely closed means 700 W/m^2 cooling needed)

How the close the greenhouse?

The design with an air distribution system in the greenhouse and an air conditioning unit is most promising

Source: www.innogrow.nl

How to produce cold water?

- Cooling machine (gas or electrical powered)
- Cooling tower (evaporative cooling)
- Using water surface area like lake of bassin
- Electrical heat pump
- Gas powered heat pump

Cooling machine

Produces cold water during warm periods
The capacity can be reduced with a short term buffer
Advantages:
- Cold water is always available
- No long term heat storage needed

Disadvantages:
- High energy costs
- Heat is not used in the greenhouse

Cooling tower

In winter ($T_{outside}$ < 10°C) cold water is produced and stored in a long term buffer
Advantages:
- No costly equipment needed
- Low operational costs

Disadvantages:
- Long term heat storage in the ground needed

Surface heat exchanger

Water bassin is used to cool water in winter
Advantages:
- No costly equipment needed
- Low operational costs

Disadvantages:
- Large surface area needed (5 times the area of the greenhouse)

Electrical heat pump

The heat pump produces heat in winter to warm the greenhouse and the cold water is stored in a long term buffer
Advantages:
- Heat used in greenhouse (the heat production covers twice the greenhouse heat demand)

Disadvantages:
- High energy consumption
- Long term buffer needed
- Low temperature heat

Gas powered heat pump

The heat pump operates with a CHP
Advantages:
- Heat used in greenhouse (the heat production covers three times the greenhouse heat demand)
- CO_2 production for enrichment

Disadvantages:
- High energy consumption
- Long term buffer needed
- Low temperature heat

Economic evaluation (EURO/m^2)

Method	Operation	Invest	Overall
Cooling machine	9	47	14
Cooling M (gas)	4	97	14
Cooling tower	3	67	10
Surface	1	69	8
Elect. HP	16	111	27 (+84 m^3)
Gas HP	15	161	31 (+130 m^3)

Gas: 23 ct/m^3, elect: 8 ct/kWh, 2000 MJ/m^2 needed, 4 Ha, 10% interest, depreciation and maintenance

Conclusions

- Cooling a greenhouse using a chiller is not economically feasible
- Using a cooling tower or a open surface area can be made economical
- Using the heat produced during the cooling makes the concept feasible but the low temperature heat has to be applied elsewhere

Future research

Technically closing the greenhouse is possible and the WANTED climate can be realized

The question is: What is the wanted climate?

What is the optimal temperature, relative humidity, CO_2 level for a given light intensity?

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Thank you for your attention