# Conditioning in an Organic Greenhouse

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**Abstract**

**Organic growers in the Netherlands have to cope with ambitious goals for the emission of $CO_2$, which in practice requires that less fossil fuel is used for heating. With conditioning, the greenhouse air can be cooled and/or dehumidificated mechanically, so that excess summer heat is collected and can be stored in aquifers for reuse with the help of a heat pump in winter. The required energy can be provided through green electricity instead of fossil fuel for heating.**

**Experiences with closed greenhouses have shown that mechanical cooling lowers the need for ventilation, thereby decreasing the $CO_2$ emission and pest pressure. In addition, conditioning can give a more balanced indoor climate and allows for a better management of humidity, which greatly reduces the chance of outbreak of *Botrytis* and similar diseases. Wageningen UR Greenhouse Horticulture is carrying out a dedicated research with an organic grower who operates a conditioned greenhouse. In this project, the main objective is to find out in what way the advantages of cooling are helpful, or can be improved for organic production, in view of the very strict requirements about application of plant protection chemicals.**

**Conditioning an organic greenhouse may give higher yield and a better control of diseases and insects, but not enough references are available to give a significant comparison.**

## INTRODUCTION

Organic greenhouses in the Netherlands emit more $CO_2$ per unit of produce than conventional greenhouses (Kramer et al., 2000; Spruijt-Verkerke et al., 2002). Although the energy use per unit of organic produce has decreased in the last decade (Raaphorst, 2009), organic growers still need to make more of an effort to show that their produce can be more environmentally friendly than conventionally-produced flowers and vegetables. That is why BiJo, a greenhouse company growing organic vegetables in the Netherlands, started a conditioned greenhouse. With conditioning, the greenhouse air can be cooled and/or dehumidified mechanically, so that excess summer heat is collected and stored in aquifers for reuse with the help of a heat pump in winter. In this way, the required energy can be produced using green electricity instead of fossil fuel for heating.

Mechanical cooling lowers the need for ventilation, thereby decreasing pest pressure. In addition, conditioning can give a more balanced indoor climate and allows for a better management of humidity, which greatly reduces the chance of outbreak of *Botrytis* and similar diseases. Both these factors can be particularly helpful in organic production, in view of the very strict requirements for application of plant protection chemicals. In a greenhouse where $CO_2$ fertilization is applied, this would have the additional advantage of decreasing $CO_2$ emissions.

Wageningen UR Greenhouse Horticulture, in cooperation with GreenQ, carried out a research project with BiJo. The use of energy, the effects on the indoor climate and the impact on the produce were the main topics.

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## MATERIALS AND METHODS

The greenhouse of BiJo consists of several sections. The smallest and newest section is a 2.5 ha venlo-type greenhouse where fruit vegetables (tomato, sweet pepper and cucumber) are grown. These crops need to be heated, and the average air temperature is maintained at 18 to 20°C. If the greenhouse air temperature increases to a level that is higher than necessary for the growth (22–27°C, depending on the global radiation rate), or if the relative humidity of the greenhouse air exceeds 85%, the greenhouse is cooled or dehumidified with an air conditioning device. This air conditioning device can also support the low temperature (40°C) heating pipes with the distribution of heat in the greenhouse. The hose pipes can be moved vertically up and down, depending on whether heating or cooling is required.

The largest and oldest section is a 7 ha wide-span greenhouse, where green vegetables that do not need much heat are grown. This section can be heated with a relatively low water temperature (±20°C), using heat exchangers with fans and large hose pipes. This section cannot be cooled or dehumidified mechanically, but only uses the low temperature heat that is harvested in the conditioned section with fruit vegetables (Fig. 1).

Heat and cold are provided by three heat pumps which use green electricity. A boiler that can be heated with bio-oil is installed as a backup and is used for heat supply during peak demand.

$CO_2$ for the enrichment of the greenhouse air, to improve the photosynthesis rate, is bought from a supplier because an electric heat pump does not produce any $CO_2$. The bio-oil burner can produce $CO_2$, but $CO_2$ from bio-oil is more expensive and gives a higher risk of polluting the air in a semi-closed greenhouse.

All the climate and energy data were collected from the climate computer (*Priva Intégro*) and analyzed using pivot tables (Microsoft Excel).

## RESULTS AND DISCUSSION

Conditioning had a direct impact on the $CO_2$-concentration, the humidity and the energy use of the greenhouse. Indirectly it affected yield, quality and pest control.

### Temperature

A 24-h average temperature that exceeds 25°C can negatively affect the anthesis of fruit vegetables like tomato (Sato and Peet, 2005). Cooling the greenhouse with an air conditioning device can avoid problems with the anthesis. However, with a moderate outdoor climate near the coast of the Netherlands and a standard unconditioned greenhouse, the 24-h average temperature rarely exceeded 25°C. In fact, the temperature of conditioned greenhouses hardly differed from unconditioned greenhouses in the Netherlands.

### $CO_2$-Concentration

If the greenhouse was kept closed during the night, the $CO_2$-concentration exceeded the range of the $CO_2$-sensor (3000 ppm). This was partly caused by the $CO_2$ emission of the crop and mainly caused by the emission of decomposition gases from the soil and the organic fertilizers. Because very high levels of $CO_2$ and other decomposition gases have been shown to damage the crop (de Visser et al., 2004), the vents were opened to remove these gases if the $CO_2$-concentration was higher than 2000 ppm.

In greenhouses without active cooling possibilities, the vents had to be opened during periods of high global radiation and a high outside temperature. The $CO_2$-concentration in the greenhouse could not be kept much higher than the outside concentration. Five hundred ppm is a common $CO_2$-concentration in a greenhouse with $CO_2$-enrichment and wide open ventilators. In a conditioned greenhouse, the ventilators rarely have to be wide open, so that the $CO_2$-concentration in the conditioned greenhouse can increase to a level of 800–1000 ppm. This high $CO_2$-concentration during high global radiation is supposed to give a 12% higher photosynthesis level than at a level of 500 ppm (Nederhoff, 1994).

The achieved $CO_2$-concentration in the conditioned organic greenhouses of BiJo during the summer days was between 600 and 1000 ppm. This means that not all the possibilities of a conditioned greenhouse with increased $CO_2$-concentration were achieved.

**Humidity Level**

In a conditioned greenhouse, it is possible to keep the humidity at almost any desired level. The cold water in the air conditioning device can have a temperature of ±10°C. While a dew point of 10°C corresponds with an absolute humidity of 9.4 g $m^{-3}$ and the greenhouse air is kept at a temperature of 18°C (saturation vapor density is 15.4 g $m^{-3}$), the relative humidity of the injected greenhouse air can be kept at 9.4/15.4*100%=61%. This is much lower than necessary. The air conditioning device at BiJo has a minimum airflow of 30 $m^3$ $m^{-2}$.h, so at a greenhouse temperature of 18°C and an absolute humidity of 11.6 g $m^{-3}$ (RH=85%), the dehumidification level can be 30*(11.6-9.4)=66 g $m^{-2}$ $h^{-1}$, which is more than twice as much as the crop evaporation during the night.

**1. CASE 1: Low Global Radiation.** If no cooling but only dehumidification is needed, the air conditioning device needs a higher water temperature than 10°C. This means that a large volume of greenhouse air is cooled and reheated for only a small quantity of dehumidification. Dehumidification with outside air would need less energy for reheating. The only advantages of dehumidification with an air conditioning device are the harvest of heat and the maintenance of a high $CO_2$ level in the greenhouse. At BiJo, these advantages were mostly insignificant, thus dehumidification generally took place with a small opening in the energy screen and the ventilators in combination with additional heating.

**2. CASE 2: High Global Radiation.** With a high global radiation, the greenhouse needs to be cooled. Cooling with outside air lowers the humidity more than cooling with an air conditioning unit. A very low relative humidity (RH) of the greenhouse air increases the risk of water stress in the plants. During periods with high global radiation, the RH in the BiJo greenhouse was only lower than 60% accidentally. The average RH during radiation higher than 800 W $m^{-2}$ was 82% in all the cooled sections. If these sections had been cooled with outside air, the average RH would have been ±67%.

**Distribution of Humidity**

The distribution of the absolute humidity is affected by the way of dehumidification. With cucumber and tomato, the cooling and dehumidification took place at the bottom of the crop during the daytime. Figure 2 shows that the absolute humidity during the daytime averaged 2.5 g $m^{-3}$ lower at the bottom of the crop than at the top of the crop. During the nighttime, hardly any dehumidification took place through the hose pipes and the absolute humidity was then higher at the bottom of the crop because the crop was the source of evaporation. With sweet pepper, the hose pipes were generally near the top of the crop, so the absolute humidity was higher at the bottom of the crop. These differences and fluctuations increased the need for more humidity sensors in a conditioned greenhouse.

**Pest Control**

In a completely closed greenhouse, it is possible to prevent insects and diseases from entering the greenhouse. However, it seems to be impossible to keep organic greenhouses completely closed because accumulation of $CO_2$ and decomposition gases needs to be avoided using air exchange. Further, dehumidification of the greenhouse air with outside air generally needs less energy than dehumidification with an air conditioning device. Therefore, the ventilators at the BiJo greenhouse were opened almost every day. Although only a reduced number of insects can enter the greenhouse if the ventilator opening remains small (Körner and Jakobsen, 2006), several insects and diseases were found in 2009 and 2010 in the crops of the conditioned greenhouses.

After insects or diseases have entered the organic greenhouse, their populations must be controlled with biological products. Many predators that are used to control arthropods are less tolerant of low humidity than their prey. Many diseases only thrive under conditions of a very high humidity. While a conditioned greenhouse makes it possible to control the humidity, pests and diseases should be controlled as well.

No quantitative measurements of the occurrences of pests and diseases were made in the conditioned organic greenhouse of BiJo. Also, references to an organic unconditioned greenhouse were not included in the research. Still, insects and mites seemed to be more easily controlled in a conditioned greenhouse if the right pest control means were also introduced. Also, hygienic measures during crop handling were still necessary to control diseases.

**Yield**

A higher $CO_2$-concentration and a controlled humidity should increase the yield. The yield at BiJo has been relatively high in comparison with unconditioned organic greenhouses, but too few figures of organic crop production in the Netherlands are known to make conclusions of a significant yield improvement. It might be possible that the yield improvement in comparison with other organic greenhouses is also caused by the freshness of the soil. Many organic growers have to cope with nematodes and soil fungi after a few years of growing fruit vegetables in the same soil.

**Energy Use**

The use of heat in the conditioned greenhouse is more or less the same as in an unconditioned greenhouse. From January to July 2010, the heat demand at BiJo was 800 MJ $m^{-2}$. The main difference in the energy use at BiJo was that most of the heat was produced in a heat pump. The coefficient of performance (COP) of the heat pump averaged 6.5. This means that with 1 kWh of electricity, 6.5 kWh of heat was produced. Only electricity from renewable sources was purchased. Further, a bio-oil boiler was used during peaks in the heat demand. Because heat from bio-oil was much more expensive than from a heat pump, the use of the bio-oil boiler was kept to a minimum.

## CONCLUSIONS

Conditioning an organic greenhouse may give higher yields and better control of diseases and insects, but not enough references are available to give a significant comparison.

When neither extra $CO_2$ nor harvested heat is needed, the most energy efficient way of dehumidification is with open ventilators. Dehumidification with an air conditioning device needs electricity for the fans and more heat to reheat the cooled and dried air.

Conditioning in The Netherlands mainly gives advantages for the $CO_2$-concentration and the humidity in the greenhouse. A lower temperature is rarely needed for fruit vegetables in the Netherlands.

Cooling from the bottom of the crop gives a different distribution of the absolute humidity than dehumidification from the top of the crop as seen with the ventilators. Thus conditioned greenhouses that can dehumidify from both levels need more humidity sensors than conventional greenhouses.

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**Literature Cited**


de Visser, P., Gorissen, T. and van der Zweerde, W. 2004. Gasemissie na toediening van organische meststoffen in de glastuinbouw: risico's op plantschade in gesloten kassen [Gas emission after provision with organic fertilizers in the greenhouse horticulture: Risks of plant damage in closed greenhouses]. Plant Research International. Wageningen, Nederland. (in Dutch)

Körner, O. and Jakobsen, L. 2006. A thrips pest pressure model for greenhouse climate control. Acta Hort. (ISHS) 718:407–414.

Kramer, K.J., Ploeger, C. and van Woerden, S.C. 2000. Biologische glasgroenteteelt – Tussenrapportage bedrijfseconomische en milieukundige aspecten 1998–1999 [The cultivation of fruit vegetables in organic greenhouses - Report of business economic and environmental views]. Project 1211, Proefstation voor Bloemisterij en Glasgroente, Naaldwijk, Nederland, 44p. (in Dutch)

Nederhoff, E.M. 1994. Effects of CO2 concentration on photosynthesis, transpiration and production of greenhouse fruit vegetable crops. PhD. Thesis, Wageningen Agricultural University, Wageningen, Nederland. 213p.

Raaphorst, M. 2009. Ontwikkeling in de energie-efficiëntie in de biologische glasgroenteteelt 1998-2008 [Development of energy effciency in the cultivation of fruit vegetables in organic greenhouses]. Wageningen UR Glastuinbouw. Bleiswijk. (in Dutch)

Sato, S. and Peet, M.M. 2005. Effects of moderately elevated temperature stress on the timing of pollen release and its germination in tomato (*Lycopersicon esculentum* Mill.). J. of Horticultural Science and Biotechnology 80:23–28.

Spruijt-Verkerke, J., Schoorlemmer, H., van Woerden, S., Peppelman, G., de Visser, M. and Vermeij, I. 2002. Duurzaamheid van de biologische landbouw [Sustainability of organic agriculture]. p.110, Report number 328, Praktijkonderzoek Plant en Omgeving, Lelystad. (in Dutch)


**Figures**

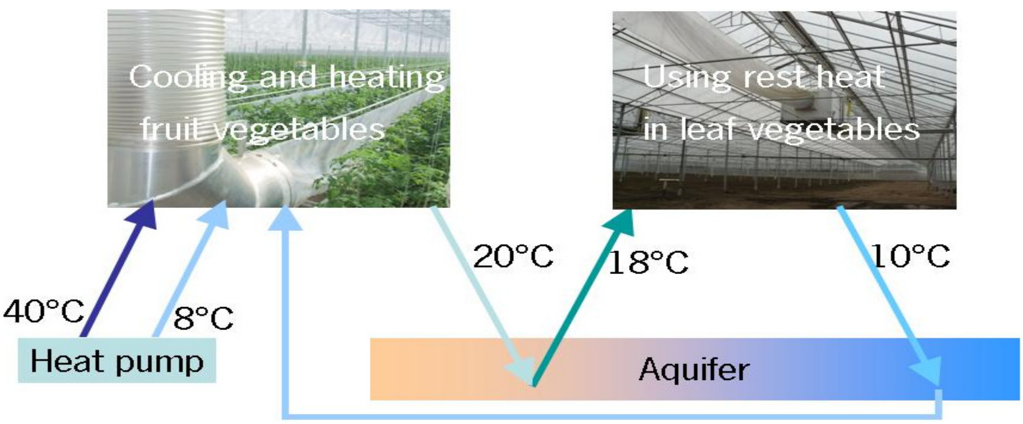


Fig. 1. The heat pump provides the fruit vegetables with cold and heat. The harvested summer heat is stored in an aquifer before heating the leaf vegetables in the winter.

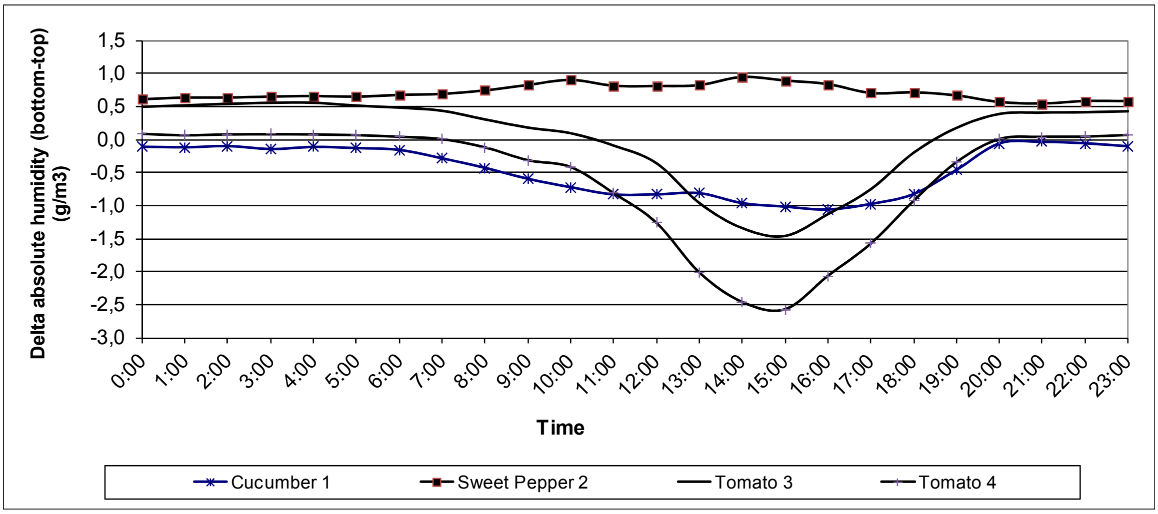


Fig. 2. Cycle mean of the difference in absolute humidity (g $m^{-3}$) between the top and the bottom of the crop in four conditioned sections. Cycle mean is between 1 April 2010 and 5 June 2010.