Tableau 6. Rendement des plants et calibre des fruits.

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Optimising fruit load and stem density of organic tomato grown under a semi-closed greenhouse

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Introduction

In northern climates, the greenhouse industry is in development. This can be explained by the growing consumer demand and the recent development of highly efficient technologies.

It has been shown that productivity can be increased through a better management of the greenhouse microclimate. This is why alternative models called closed and semi-closed greenhouses were developed in the Netherlands in the early 2000s. These systems use geothermal systems to ensure greenhouse cooling and/or heating (Nederhoff et al., 2010). This allows the roofs to remain mostly closed, which leads to a greater control of humidity and temperature as well as maintaining high CO_2 concentration in the greenhouse (Opdam, 2005).

High CO_2 concentrations can, to a certain degree, compensate for a reduction in luminosity (Dannelh et al., 2014). Heuvelink et al. (2007) suggest that the density could be increased by at least 17% in a closed greenhouse following the elevation of the biomass production of 17%, while maintaining the desired fruit size. Observations at Serres Jardins-Nature (Qc, Canada) also showed that fruit load and density were higher in semi-closed than in open greenhouses in 2015. No study has previously focused on stem density and fruit load control in semi-closed greenhouse.

To evaluate the effect of non-traditional cooling and dehumidification technologies on crop management, the objective of the study was to compare density and fruit load treatments in a semi-closed greenhouse context by comparing yield, fruit size, crop growth, climate parameters and fruit quality.

Materials & Methods

- Two experimental double polyethylene 225 m² compartments located at Les Serres Jardins Nature, Qc, Canada (48.1505, -65.8355) were used during 2015 growing season (January-October). Those two semi-closed compartments (R2 and R3) were cooled using water from the water table (12°C) which was directed in a heat exchanger. Polyethylene tubes located above the canopy then ensured the airflow.

- In the organic soil grown crop, three stem density treatments (3.0, 3.3 and 3.6 plants/m² with 42, 46 and 51 plants per experimental unit, respectively) and three fruit load treatments (70, 85 and 90 fruits per m² with 67 plants per experimental unit) were compared using a Latin square design.

- Argus Greenhouse Management System (Argus Control System, White Rock, British Columbia, Canada) was used for climate monitoring. Crop growth parameters were measured on a weekly basis following Tom'Pousse procedure. Yield and fruit size were monitored weekly. Fruit quality parameters (color, firmness, fresh and dry mass, carotenoids, phenolic compounds, ascorbic acid, soluble sugars, titrable acidity and electrical conductivity) were analysed for each treatment in august and October.

Fig 1. Experimental semi-closed compartment

Climate, CO_2, Geothermal system, cooling

Results & Discussion

- For the density treatments in R2, both week yield and cumulative yield were higher at density 3,0 plants/m² than at 3,3 or 3,6 plans/m² as showed in fig. 1., suggesting that this stem density could be advocated to maintain the desired fruit size.

- In the R3 compartment, it was the lowest fruit load that presented the highest yield and fruit size. This is consistent with the dry matter results, where the percentage of dry matter was decreasing with the augmentation of the fruit load as showed in fig. 1.

Table 1. Production results in terms of fruit yield and fruit size for 2015 growing season in two semi-closed compartments

Treatment	Fruit size (g)	Yield (kg/m²/week)	Cumulative yield (kg/m²)
R2 D. 3.0	238 ± 32	1,92 ± 0,87	58,76 ± 7,23
R2 D. 3.3	237 ± 32	1,77 ± 0,68	54,14 ± 1,98
R2 D. 3.6	223 ± 36	1,77 ± 0,72	54,38 ± 4,85
R3 C. 70	228 ± 21	1,87 ± 0,82	57,83 ± 2,70
R3 C. 80	224 ± 26	1,81 ± 0,84	56,08 ± 4,72
R3 C. 90	223 ± 28	1,73 ± 0,70	53,53 ± 3,16

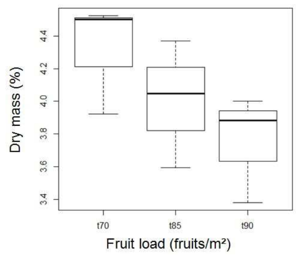

Fig. 1. Percentage of dry matter for the three fruit load treatments for August 2015 harvest

- Growth parameters (Table 2.) as elongation, stem diameter, and apex-flower cluster distance were higher in R3 than in R2 compartment (where stem density was 3,6 plant/m² and fruit load between 70-90 fruit/plant depending on the treatment).

Table 2. Growth parameters for the six treatments means for 2015 growing season in two semi-closed compartments(D= stem density; C= fruit load)

Treatment	Elongation (cm)	Stem diameter (mm)	Mature leaf length (cm)	Apex-flower cluster distance (cm)	Flower set (cluster/ week)	Fruit set (cluster/ week)
R2 D. 3.0	19,5 ± 4,4	10,7 ± 1,5	53 ± 6	11 ± 3	0,75 ± 0,47	0,75 ± 0,39
R2 D. 3.3	19,2 ± 4,7	10,7 ± 2,2	53 ± 7	10 ± 4	0,76 ± 0,38	0,74 ± 0,39
R2 D. 3.6	19,3 ± 4,7	10,7 ± 1,5	53 ± 6	10 ± 3	0,73 ± 0,40	0,71 ± 0,40
R3 C. 70	21,1 ± 4,6	11,2 ± 1,6	53 ± 5	11 ± 4	0,80 ± 0,41	0,78 ± 0,44
R3 C. 80	21,3 ± 4,8	11,0 ± 1,5	52 ± 6	11 ± 4	0,79 ± 0,41	0,78± 0,44
R3 C. 90	21,1 ± 4,8	11,3 ± 4,4	53 ± 5	11 ± 4	0,75 ± 0,41	0,73 ± 0,41

- The day and 24h averaged temperature was respectively 1°C and 0,6°C higher in the R3 than in R2 compartment as show in table 3. However the night temperature was similar for the two compartments.

- The relative humidity was also higher for the averaged day and 24 h by respectively 0,6 and 1% in the R3 compartment comparatively to the R2 compartment.

Table 3. Climate parameters for the two semi-closed compartments for 2015 growing season.

Compartment	Day temperature (°C)	Night temperature (°C)	24 h Temperature (°C)	Day relative humidity (%)	Night relative humidity (%)	24 h Relative humidity (%)
R2	20,7 ± 2,4	18,4 ± 2,3	19,6 ± 2,1	85,6 ± 5,3	85,8 ± 7,4	85,5 ± 6,2
R3	21,7 ± 2,5	18,5 ± 2,1	20,2 ± 2,1	86,2 ± 8,9	85,8 ±10,8	86,5 ± 9,4

- The CO_2 concentration was maintained 46 $\mu L\ L^{-1}$ higher in the R2 than in R3 concentration. This compartment , while having maintained the highest CO_2 concentration required less injection of the gas. In fact the injection per day was 14 g/m² less in R2 than in R3.

Table 4. CO_2 concentration and injected in the two semi-closed compartment for 2015 growing season.

Compartment	CO_2 ($\mu L\ L^{-1}$)	CO_2 injected (g/m²)
R2	681 ± 138	97 ± 41
R3	635 ± 136	111 ± 43

Conclusions

- The difference in the air temperature, the relative humidity and the CO_2 concentration can be influenced by the roof opening time or the different efficiencies of the two systems.

- The difference in CO_2 concentration between the two compartments is very interesting. The R2 compartment maintained higher CO_2 concentrations and needed less CO_2 injection. The R2 compartment ran at a lower overall CO_2 injection cost and maintained higher CO_2 concentrations for the crop.

- Given the strong presence of *Verticillium*, the producer is turning from soil to hydroponics. It would be interesting in the context of an upcoming project to study the fertilization needs in a semi-closed hydroponic greenhouse.

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Acknowledgements

This research is funded by the Canadian Organic Science Cluster. The Organic Science Cluster is funded by the Canadian Initiative on Canadian Agri-Science Clusters, the Growing Forward Policy Framework for Agriculture and Agri-Food Canada and its industry partners. Thanks to Agriculture and Agri-Food Canada (AAC) for financial assistance and to Serres Jardins-Nature, Réjean Bacon and Claudine Ménard for technical advice.

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