In this post, I share my experience with the semi-closed glasshouse. There is much confusion on how best to grow crops in a semi-closed glasshouse, and this series of articles tries to clear up confusion, inspire new discussion and educate.

Increased CO2 levels in a Semi-Closed Glasshouse

CO2

CO2 plays a major part in the production of glasshouse crops. Carbon (the C in CO2) is the second most abundant element that makes up a tomato plant. (Water makes up 80% of the plant, carbon makes up half of the remaining 20%). Most of that carbon is taken up by the plant via the absorption of gaseous CO2 through the photosynthetic process. It's amazing to think that a tiny concentration of 400 ppm atmospheric CO2 (0.04%) can help create enough trees, plants, fruits, and vegetables to feed all people, animals, and insects in the world. It makes sense then, that increased level of CO2 results in yield increases.

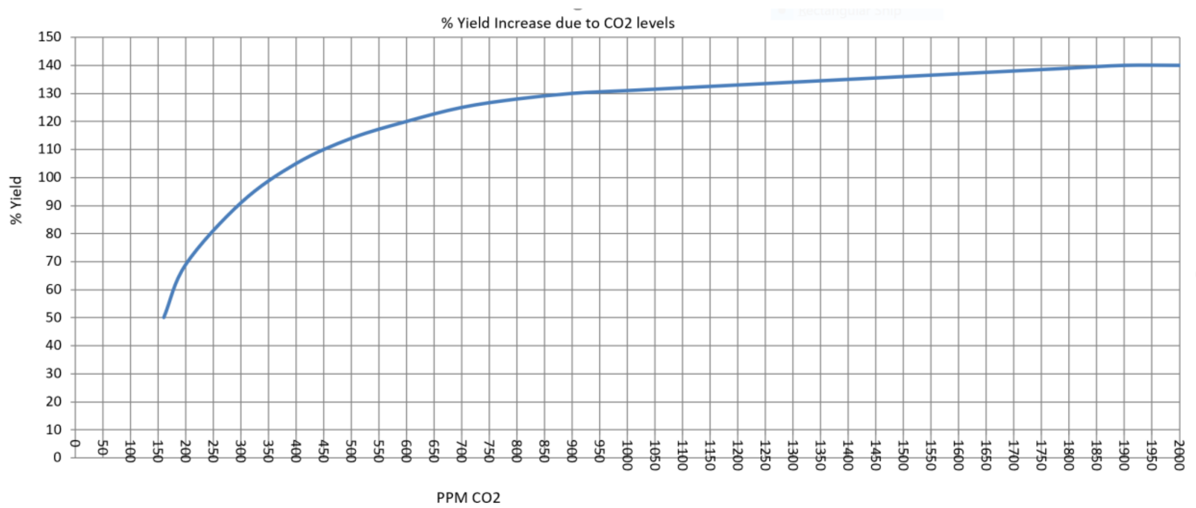

Fig 1; Effect of CO2 on yield

How much CO2 levels increase yield in tomatoes is presented in the graph above. The graph dates back to the 80's when ambient CO2 levels were still 350 ppm. This is where a 100% yield is indicated. Today's CO2 level has risen to 400 ppm, which results in a 3% yield increase of tomato crops worldwide! At 2000 ppm the yield increases to 40%. The line flattens beyond 2000 ppm. There are still benefits concerning yield at CO2 levels above 2,000 ppm, but in general, the cost-benefit relationship suffers and there is an added risk, if boiler CO2 is used, of high levels of carbon monoxide, ethylene NOx and Sox. These yield increases can only be achieved when all the other parameters that are important to growing are also at optimum levels. There needs to be enough light, not too hot or cold, the right humidity for the stomata to be open. A vegetative plant will transform CO_2 into leaves whereas a generative plant will put the CO_2 to use in bigger fruit. Note that the graph shows that low levels of CO_2 can significantly reduce yield. This situation can occur when it is cold enough outside to have (almost) zero air exchange and plants suck the available CO_2 out of the air if the air is not replenished with additional CO_2.

The maximum CO_2 levels that can be maintained in a glasshouse depends largely on how many times the air is exchanged in the glasshouse. Plant uptake is a much smaller factor. It stands to reason that if less air is exchanged, the CO_2 levels in the glasshouse will rise. A comparison of the air exchange of three types of glasshouses are shown in the table below.

If we look at the conventional glasshouse first, the air exchange can be calculated from the vent positions and outside wind speed. (For this calculation we ignore wind direction). For instance, based on a wind speed of 4 meters per second, and a wind side opening of 11% and a lee side opening of 100%, the entire glasshouse air is exchanged 7 times per hour. This corresponds with a fan speed of 60% in a semi-closed glasshouse. (see note). In warm weather, vents must open further in a conventional glasshouse, fans must run faster in a semi-closed glasshouse, increasing air exchange and reducing CO_2 levels.

Semi-Closed Fanspeed	Conventional Glasshouse			Air Exchanges per hour	Increased CO2 level at injection rate of 100Kg/Hr in PPM	%Increased Yield at increased CO2 level
	Lee	Wind	Wind Speed			
30%	46%	0%	4 m/s	4	50	7.0%
40%	80%	0%	4 m/s	5	40	5.0%
50%	100%	5%	4 m/s	6	35	4.0%
60%	100%	11%	4 m/s	7	28	3.0%
70%	100%	18%	4 m/s	8	26	2.8%
80%	100%	26%	4 m/s	9	22	2.6%
90%	100%	33%	4 m/s	10	20	2.4%
100%	100%	41%	4 m/s	11	18	2.2%
N/A	100%	49%	4 m/s	12	16	2.0%
N/A	100%	57%	4 m/s	13	12	1.5%
N/A	100%	66%	4 m/s	14	10	1.0%
N/A	100%	75%	4 m/s	15	6	0.5%
N/A	100%	100%	7 m/s	30	0	0.0%
N/A	100%	100%	14 m/s	60	0	0.0%

Fig 2; Air exchange and CO_2

In the table, the second column from right shows a calculated CO_2 level increase when 100KG CO_2 per Ha per hour is injected into a glasshouse corresponding with the number of air exchanges per hour. Higher air exchange results in less CO_2 being added to ambient levels. The right column reflects the increased yield level as a result of the increased CO_2 level (as per Fig 1) for each level of air exchange.

NOTE ON FAN SPEED

Please check the capacity of the fans to make sure the percentage fan speed corresponds with the figures used here. Different glasshouse manufacturers use different fan capacities.

If we look at the high air exchange end of the table, it shows that CO_2 injection in conventional glasshouses has no positive effect on yield when both wind and lee side vents are 100% open. The semi-closed glasshouse can keep a glasshouse cool under the most extreme conditions by applying a fan speed of 70%. At this speed the air exchange is low enough to improve the CO_2 level to 26 ppm, increasing the yield by 2.8%. This is only one scenario at a certain air exchange at a certain time of the day, at an injection rate of 100 Kg/Hr CO_2, but it validates the fact that there is a CO_2 yield benefit due to the more efficient cooling of the semi-closed glasshouse. The evaporative cooling can also be perfectly modulated when outside conditions are cooler. The effect of cooling the outside air before it enters the glasshouse will result in less air exchange and increased CO_2 levels.

If we repeat the same experiment, but now at 200 Kg of CO_2 per Hectare per hour, the benefits double both in ppm and percentage yield increase. For proper calculations of the benefits of CO_2, the cost of CO_2 and the price of the produced product must be also considered.

At low air exchange levels, the semi-closed glasshouse can also provide benefits for CO_2 uptake. Semi-closed glasshouses need a minimum fan speed of 30% to keep the ducts inflated, but that doesn't mean that all that air is lost to the outside. The recirculation window allows glasshouse air to be recirculated past the fans. The CO_2 enriched air constantly flows past the leaves, speeding up the photosynthesis process. The superior air movement not only improves the microclimate around the surface of the leaves but also allows more CO_2 to pass by the leaves. From the plants` perspective, it senses both a lower humidity and a higher CO_2 level at the leaf surface level.

To calculate exactly what the CO_2 benefit is when comparing a semi-closed glasshouse to a conventional glasshouse is complicated. Aside from the amount of CO_2, CO_2 cost, level of yield increase and product price, the outside climate also plays a part. In dry cool climates, the air exchange level can be lowered more easily than in a warm humid climate resulting in higher yields. In the worst-case scenario, during hot weather, a semi-closed glasshouse will still yield a 2.8% yield increase compared to a conventional glasshouse (see table). However, the difference could easily amount to more than 10% under cooler conditions.

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