Increasing and Diversifying Organic Greenhouse Vegetable Production (Part 1)
with Dr. A.P. (Tom) Papadopoulos

Dr. Papadopoulos has experience working with greenhouse vegetable growers in Ontario and other parts of the world. The focus of his talk was organic greenhouse vegetable production but he thought it would be useful to start with a crash course in greenhouse production in general. He thought it would be useful for those interested in organic production to learn a bit more about the larger context.

Dr. Papadopoulos works at an Agriculture Canada research centre in Harrow Ontario. Slide #2 is a 10 year old picture of the main research wing with offices and labs. The most modern greenhouses they have can be seen in the background.

Slide #3 is a picture of the research centre taken from a plane. They have the largest greenhouse research complex in North America. The greenhouses closer to the bottom of screen are used for greenhouse research. The 9 small greenhouses near the centre of the picture were built in 1987 for evaluating greenhouse structures and materials including glass, double polyethylene and acrylic. There is also another research stations that is affiliated with the reserahc station in Harrow that specific studies production in heavy clay soils.

The experiment comparing greenhouse materials and structures cost $700 000 but saved the greenhouse industry a billion dollars in heating and material costs. Most new greenhouses are double poly because it was found to takes 35% less energy to heat those greenhouses and costs half price of glass.

Slide #6 shows that Harrow is at most southern point of Canada.

Slide #7 shows that Harrow is close to Leamington where most of the greenhouses in Canada are located. More greenhouse vegetables are produced in Leamington that in the entire USA!

Slide #8 shows a map of world. The farther we go north in the world, the shorter the day gets in winter which means that the farther north a greenhouse is located, the more difficult it is to grow a crop. In addition to shorter day lengths, it is often fairly cloudy during the winter in northern locations. Light becomes limiting factor. Notice that Holland, which has a substantial greenhouse industry is much farther north than we are. Leaminton is at the same latitude as the northern border of California or Rome while Holland is as far from Rome as Rome is from Jerusalem, which is one of the locations in the globe with the highest light availability. So we’re in better position to produce greenhouse crops than much of northern Europe

Still, people often say “if you want to grow greenhouse crops, go south”. An a number of Canadians have investigated production in Mexico while producers in Holland have gone to Spain. But the most advanced greenhouse industries are in Canada, Japan and Holland. That’s because, while in the south it’s not as cold as here it is very hot in summer.

Generally it is easier to heat a space (technology and cost wise) than to cool a space. Air conditioning is very expensive and there are difficulties with evaporative cooling technologies. In the south greenhouses are generally low tech and can produce for only 3 or 4 months after which conditions in the greenhouse become too hot and too expensive to air condition. In the north, producers are already producing for 9 or 10 months of year starting in March and heating is only needed for part of that period. Due to lower temperature control needs, more money is available to invest in more expensive structures.

Q1: Have any studies looked at the advantage of longer days in June in the northern hemisphere compared with greenhouse production in the south?
A: Long days are a plus, if we can control summer temperatures (which can be more of a problem in Leamingston compared with regions with a more maritime climate like the Fraser Valley) Also, in high humidity it's hard to control heat levels.

Q2: So it's easier to do greenhouse production in a maritime climate?
A2: As far as temperature is concerned, yes. Holland is one successful example of that.

Slide #9 is a picture of Leamington's greenhouse industry 20 years ago. The greenhouses were largely located along the highway and another road. Most of the greenhouses close to highway are old glass structures and those behind them they are all double poly.

Slide #10 shows a more recent picture of Leamington's greenhouse industry. You can see that the area is now running out of space for new greenhouses. The industry is moving farther outside of the city.

Slide #11 shows a large greenhouse that covers 30 acres. It is now a bit out-dated and is no longer the biggest greenhouse in the region.

Slide #12 shows the inside of a 10 acre greenhouse that now has another 20acres attached to it.

Slide #13 shows a typical boiler room that provides heat to a greenhouse.

Slide #14 shows another boiler room.

Slide #15 shows a packing house: each greenhouse typically has its own boiler and packing house. In this photo are students of Dr. Mary Peet from North Carolina State University who came to visit Leamington. Dr. Peet is one of the pioneers of greenhouse organics and is in charge of USDA program on organic crops.

Slide #16 shows all of boxes stored in a large packing house

Slide #17 shows a pepper crop operation

Slide #18 shows a close up of those pepper plants

Slide #19 shows statistics concerning greenhouse production in Leamington and all of Ontario for 2006. Most of Ontario's greenhouses are in Leamington. Today there are 2000 acres of greenhouses in that town while in 1980 there were 220 acres.

Slide #20 shows the area under greenhouses in Leamington and the rest of Ontario. In 1980, 1 acre was a big greenhouse but now there are a dozen that are larger than 50 acres.

Slide #21 shows on a bar chart how the industry has grown over the past years in Ontario.

Slide #22 shows that tomatos, pepper and cucumbers are the primary crops grown in greenhouses in Leamington. Peppers were not grown very much 15 years ago but now they are as important of a crop as tomatoes and cukes. You might ask: Why not grow strawberries in greenhouses? Or climbing beans? Tomatoes, peppers and cukes yield the most weight of produce than other plants. You could raise other crops in greenhouses but you would have to charge a lot more for them in order to balance the costs of production. If for example you grew strawberries and the yield was one fifth the weight and equal area of tomatoes would have produced then you would have to charge 5 times as much for 1kg of strawberries than for 1 kg of tomatos. Overall, alternative crops must be sold at higher price to be competitive. That's why those three crops (tomatos, peppers and cucumbers) remain the main crops in greenhouse production.

Now there are a couple slides that talk about new technologies in greenhouse production that it could be useful for organic growers interested in greenhouse production to know about. These new technologies are listed on Slide #23.

Slide #24 shows raised troughs that are produced by a machine that takes a roll of metal sheeting and molds it into troughs.

Slide #25 shows that these troughs are hung from roof and a turnbuckle is used for minor adjustments to their height.

The troughs are all filled with soiless mediums and the plants are produced using hydroponics. There is one line that provides irrigation (containing nutrient solution) and usually another line will provide CO2 gas to the plants. This set up can be seen in the next few slides of the presentation.

The raised troughs make working in the greenhouse easier and more efficient. Workers don't have to bend down to plant, harvest, prune etc. They always work at waist height. The fruit clusters are also always at waist height. As the tomato plants grow upwards they are laid down also the troughs.

Slide #29 shows, in the middle of the picture, heating pipes and rails to move carts throughout the greenhouse.

Slide #30 shows a cuke crop in raised gutters.

Slide #31 shows that cukes grown in the troughs end up being straight from hanging and are easy to pick.

Slide #32 shows that artificial light is important for year round production. Artificial lighting dramatically increases yield in the winter months.

It generally takes more energy (light) to produce tomatoes than cucumbers, which are mostly water.

Slide #35 shows the use of artificial light in greenhouses in Canada 15 years ago.

Slide #37 shows part of a recirculation system. These large tanks contain water with dissolved fertilizer that have the desired conductivity and pH for the hydroponics system. Until recently, fluids used in hydroponic systems generally provided more water and 30-40% more nutrition than plants required because fertilizers were relativity low cost and they wanted to ensure that there plants weren't lacking nutrient or water. Those practices are no longer acceptable due to environmental concerns. Now, water and nutrients are recirculated in the hydroponics systems.

Slide #38 shows the system that adds nutrients to irrigation water. Each head feeds one nutrient into the solution and a computer controls how much of each nutrient is added. This system can be modified so you could mix a solution with different nutrient compositions each day if you wanted too. So with this system you can have a seasonal fertigation program. All a grower has to do is make sure there is enough nutrient in the machine to be mixed into solutions. Apart from that you just put in dates, what crop you're growing, what type of medium you're using and the computer takes care of rest.

Slide #39 shows large tanks of fertigation liquid in a greenhouse. These tanks are usually concrete and underground. A local bylaw states that each greenhouse must have enough storage capacity to meet their needs for 100 days. One tank contains water and the other contains excess nutrient solution. The "used" nutrient solution is tested and adjustments are made to recalibrate solution with new nutrent and water inputs. The reused solution is also cleaned/sterilized with U.V. or ozone,

Slide #40 shows U.V. water sterilization.

Q3: Don't sterile systems make it all the harder to deal with bacteria or fungus that get into these systems?
A3: Yes, it's a nightmare when something gets in. There are two main camps of thought in the greenhouse industry: one group says they need to sterilize everything and the other group thinks they need to involve microbes in their systems so that these microbial communities reach their own balance. Both are right in their own minds.

Slide #42 shows a CO2 recovery system. Generally, if we enrich air with CO2 we can get a 30 to 40% yield increase. People use natural gas to generate heat and CO2 for their systems. As long as you have a perfect combustion method, you'll have CO2 as a gas byproduct without any other toxic gases. The offgases from these systems are monitored for toxic gases and are then fed to the plants. However, the boilers for these greenhouses usually produce a lot more CO2 than can be used by the plants in the greenhouses. Maybe if you have 6 boilers, you would only need the CO2 from one boiler for use in the greenhouse.

One problem is that most of the heating is needed at night but the CO2 is needed in day. To solve this problem, producers operate the boiler in day to generate CO2 and hot water, which is stored in tanks like these (Slide #44). Then the hot water is circulated at night. This setup makes economic sense and makes the operation more environmentally friendly. This grower (in Slide #44) also built boilers that will burn alternative fuel, like waste wood.

Grow pipes are shown in Slide #46. These pipes are filled with hot water and are positioned at the growth points of the plant to stimulate growth.

Slide # 49 shows a 1700 acre greenhouse of double poly.

Now, however, it is becoming more and more important to produce year round and people think they will get a bit of extra light with glass, so some growers have started building new, large greenhouses out of glass. Also the cost difference between glass and poly has diminished in recent years.

You can see in Slides #51 and 52 that the greenhouses are often very tall. There can be twenty feet of height above the gutter to the roof of the structure. Why are we building such tall greenhouses? Air within a greenhouse stratifies with warm air rising to the top and cooler air falling. The taller the greenhouse the more opportunity there is for very hot air to stratify away from plants in the summer. Also, the environments inside these structures have large buffering capacities due to their large air volume. As a result, the air temperature inside the structure remains fairly steady and does not as respond as rapidly to changes outside the structure. Plants like these more stable conditions. Some greenhouses also have curtains for shading. Using curtains at night glass greenhouses can result in the same energy savings that would be achieve if a poly house were used.

Unlike tomatoes, peppers aren't bent down during production. Also, note that the gutters must be kept level for even growth. The pepers shown in Slide #52 are indeterminate peppers. These are different from field peppers. They tend to be sweeter, they grow to be 2 to 3 meters tall and the seeds for these plants cost 63 cents each! These seeds are sold only by two or three companies.

Idea of grafting has become more popular in recent years. The root stock and cultivar you want to produce are gow separately and then grafted together. The rootstock tends to be a variety that is more vigouress and disease resistance. Grafted plants will last later into the winter season than "normal" plants.

Recently the industry has had to expand the types of the three main crops that they produce because markets were becoming saturate. One example of a “new” crop that has been produced by the industry is cluster tomatoes. People really like them because the stem smells great and as a result people think the tomato smells good. This crop has recently increased in popularity.

Slide #62 shows a heating system that uses woodchips. It’s a $3 million operation. They need 2 barns to store their wood chips so that if one barn burns down, their greenhouse won’t freeze over.

Slides #64 and 65 show the idea of raising potted plants inside the greenhouse to provide extra income and shading.

Slide #65 to 67 show different types of tomatoes on market in France, including black tomatoes.

And that is the end to the introduction to the current greenhouse industry.

Q4: Is anyone looking at other types of alternative energy? Geothermal?
A4: Dr. Papadopoulos hasn’t done energy research but he is aware of energy related research in Canada and in Leamington. Geothermal is of particular interest in regions with hot-springs but there are concerns about contaminates in the waters and gases of those springs.

Q5: Can tomatoes in greenhouses taste as good as tomatoes from the garden?
A5: The market speaks for itself. Greenhouse tomatoes are a successful crop and there are people who will pay higher prices for greenhouse tomatoes. In scientific terms, how do we compare a greenhouse tomato with garden tomato? It’s so relative…everyone has preconceived notions, past experiences relating to tomatoes plus there are so many different tomatoes and different expectations of tomatoes should taste like. However, taste tests show they can be same.

Part 2:
The market opportunity is there for organic greenhouse crops and there is lots of room for growth. Tomatoes currently make up only 4% of organic produce grown in Canada.

In last 5 years, Canada has become a next exporter of tomatoes to the US because Leamington went from 200 acres of greenhouses to 2000 acres of greenhouses while the industries in Quebec, Alberta and BC have also grown. All that has resulted in concerns of how much more we can grow and how many more vegetables we can sell. And what if there is someday a food safety scare related to greenhouse crops from Canada? Overall, growers are starting to look for new and different marketing opportunities.

Scientists and growers get together a couple of times each year in southern Ontario to discuss research ideas and results. A few years ago there was not a lot of interest in organics in Leamington but now there is more interest.

Also, in the past, marketing to US was more successful due to the weak Canadian dollar. However, now that the dollar is stronger, a lot more produce is being imported to the US from Mexico.

Government policy changes that have made organic growing a new priority have contributed to the increase in interest in organics within the industry.

Dr. Papadopoulos was involved with submitting a proposal to Ontario, BC and Quebec growers to do research related to organic greenhouse production. It took one year to come to an agreement with all of the groups.

A list of groups that contributed funding to the research can be found on Slide #76.

The project had a 3 year plan and finished in the middle of last year, which was a bit later than expected. As part of the project the made their own growing media since appropriate media was not readily available.

The experiments involved liquid fertilizers, which were said to be essential to make sure the right nutrient ratios were provided to the plants. It is hard to get ideal nutrient release without liquid fertilizer applications. Nutrients can also be applied with side dressings and that was also looked into.

In beginning, they tried two liquid feeds. “Pure bled” liquid feed is not certified and in the end “Agro Chem” was certified for use in organics. There are also other desirable chemicals available.

They also tried incorporating different amounts of soymeal into their growing mediums. A big problem with organic medium is their inability to supply nitrogen to plants. Lots of soybeans are grown in the area where the experiment was taking place and are processed in Windsor. The processing company donated soymeal to the researchers. It was thought that the high protein in the soybean meal would provide extra nitrogen. The use of plant based materials in the preparation of the growing medium was considered desirable because they tend to have a consistent composition unlike manure.

Slide #84 shows the growing media mixes composting in a field. The piles were covered in plastic to reduce nutrient lost. The medium was turned each week and sampled for two months. After that point, the mix appeared to be stable. Some of the material prepared during this initial composting was used a year later and was still good.

The first planting in the experiment took place on Jan 17th, which is a typical date for greenhouse planting. However, sometimes it is easier to plant later. One needs to be more careful to unsure that there isn’t too much vegetative growth. If we start crops in the middle of winter, we need to restrict the water supply and nutrients to the plants in order to hold back vegetative growth in low light availability and to ensure the plants set. First fruit set is generally worth the most.

Slide #94 shows the first experimental layout. In each block, both of the 2 liquid feeds. Four growing medium (10, 20 and 50 kg soymeal and commercial medium) were also tested.

Slide #95 and 96 show the set up at the beginning of the experiment. Pots were set up in troughs to collect leachate (excess solution).

The tomato plants grew very well. On March 6th, leaves were removed from the plants to provide better air circulation and reduce disease pressure.

The plants appeared to be a bit nutrient stressed in late March but in April more that three or four clusters had formed, which was more than had been hoped for. In April the plants were laid down. Then in may they were laid down again.

Slide #126 shows some of the buckets used for nutrient solution capture. Pumps return the leachate to holding tanks.

In June, there were problems with some treatments, but overall the crop was not too bad.

Before starting the experiment, the scientists had been warned about problems with irrigation drippers clogging when used with organic medium. To solve this problem, they put a spigot in each pot but this probably wouldn't be practical for commercial scale growers. More work is currently being done in BC on this issue. They have found that better filtration can help prevent clogging.

The scientists originally thought the plant in Slide #135 to 137 had iron deficiency, but it was in fact a P deficiency.

This experiment also involved sidedressing with composted soymeal but it was found that side dressing didn't make much different so its use was eliminated from future experiments. In this first experiment, pots were only filled two thirds to allow for side dressing but in later trials the pots were filled completely.

In conventional production a high concentration fertilizer/water mix is used during the winter because the water in this mix will be less availability due to the high conductivity of the solution. The humidity in the greenhouse can also be reduced by cracking the greenhouse's vents in order to mildly stress the plants. Overall, heating and ventilating controls plant water uptake and can effect fruit set. But in organic operations, the nutrient contents of solutions and media are so low and more expensive so using more nutrient in solutions is not practical.

Another project looked at how changing nutrient solution conductivity affected tomato fruit quality. Higher conductivity resulted in higher fruit quality but their were environmental concerns about the environmental implications of those practices because at that time nutrient solution recycling wasn't commonly practiced. So, another alternative practice that was looked at involved adding salt to the nutrient solution and it was found ot also increase fruit quality. The results of this experiment are published.

The next set of experiments were conducted between spring 2006 and spring 2007. During these experiments, only the 20 and 40 kg soymeal media were used. The commercially available media was eliminated from the experiment because they wouldn't contribute funds (or their media) to the project and were secretive about their ingredients. Agro-green (a liquid fertilizer) was also incorporated into the experiment because they donated liquid fertilizer for that year. Pure blend was included in the experiment in the second year because although it is not certified for use in organic growing it performed well. The original experiment was criticized because it did not have controls, so organic and inorganic controls were added.

In the second year, nitrate was higher than in the first year and this might have been due to starting the composting to make the growing media in June and July instead of August to September.

Slide # 152 shows the EC of leachate and fertigation fluids during the two experiments. These results indicate that there were plenty of nutrients available to the plants since the EC of the leachate was higher than the fertigation fluid. The solid line is the EC of an inorganic feed.

When negotiating legal agreements with Ontario and BC to gain funding for this work, part of the deal was that the results could not be available to the general public for a period of time after the results were complete. The reports discussion these experiments and their results are only now available to the public.

Note on Slide #153 that the phosphorus levels for the treatments using AgrowChem were quite low.

Slide #154 shows the yield results for the experiments, which weren't bad. Experimental set-ups typically cannot match commercial yields because in larger operations the grower spends all of his/her time monitoring the crop and is always make adjustments to ensure optimal conditions for the plant were as a researcher typically isn't dedicating all of their time ot one project. Also, smaller experimental greenhouse have less buffering capacity, which also makes it difficult to match commercial yields.

The yield for the different soymeal levels in the growing media are not significantly different but there is an obvious trend: the more soymeal in the medium the higher the yields.

Q6: Are the differences between the marketable and total yields in this study normal?

A6: More information is available in the report.

The numbers in brackets on Slide #155 are the % of commercial yields achieved in trial.

Quality evaluations were also conducted as part of the experiment. A taste panel: 8 or 9 people, rate them 1 to 10 (best), Ontario specialist, surversivor or greenhouse crew, librarian, secretary etc.
Then evaluated crate on apperance: no significant difference, more infor available in the report

Diff due to process made due to more effective mediums etc.
Note fertilizer costs more than heating for organic

The emphasis has to be on the medium. Little hope in cost of ertilizer going down. So need to try to reduce amount used and supplement with media.

In 2006, an experiment similar to the tomato experiment was conducted using cucumbers. The home made medium was placed in pots with the control media were placed in small containers.

Buckets were again used to check that the plants received the right amount of water and to provide leachate that could be tested monitor for changes in nutrient availability.

Early in season, the plants were not green enough and then there seemed to be symptoms of disease in the fall. There was not much time left in their growing season to respond to the disease, so the scientists left them. Overall, yields were low in the whole greenhouse.

The last experiment that was conducted involved peppers and the crop remained healthy throughout the season.

Plants grown in homemade media all had similar yields. Note that three different liquid fertilizer mixes were made with a variety of Agrochem products. The Agrochem products were used in different combinations that resulted in similar nutrient contents

The economic analysis of the different production regimes tested in the various experiments are available in the final reports.

Question and answer period:

Q7: Have you tested media at the end of trial to see if it can be reused?
A7: The organic method of greenhouse growing has the advantage of not having disposal problems associated with rockwool, which is usually used in commercial operations. Reuse is a possibility in organic systems but you could be putting yourself at risk to mistakes or accidents that could result in crop failure. Is it worth the risk?

Comment: One farmer in the audience uses soil from cucumber production to grow lettuce and the soil is also sold for landscaping uses.

Q8: Did you look into the disease that you noticed on the cucumbers?
A8: In the greenhouse industry, some spraying is used to control fungal diseases and only as a last resort largely because bumble bees are used to pollinate greenhouse tomatoes and they are very sensitive to pesticides. So spraying is minimal. In this particular experiment, they're not sure what disease affected the cucumbers.

Q9: In first year you used a peat based medium?
A9: Peat based media was used in both of the experiments but after the first year coco peat was used as an organic control and rockwool as an inorganic control. But basis for other media was always peat.

Q10: So single biggest factor in the cost of production is liquid fertiliser? Did you look for alternatives to those products?
A: Yes. The scientists approached as many companies as possible but the fertiliser's used in the experiments were all they were able to access. In BC others have been tried.

Q11: What was your irrigation scheme?
A11: It was time based and was the same for all of the plants. Maybe different management systems would have had different results. Overall, they tended towards over-irrigation and also used recycling leachate recycling. The leachate wasn't monitored and was just reused as it was. There didn't appear to be any problems with that system.

Q12: So there are two camps in hydroponic community including one camp that advocates incorporating microbes. Is that method used?
A12: Yes, outside of Montreal in Mirabel is the world's largest hydroponic grow house. They produce lettuce in ponds of nutrient solution and have been in business for 25 years. They have never emptied the tanks, just adds water and nutrients. Their system is not sterile. They did research into alternative herb and medicinal crops and found that they were all successful in their system.