Montreal Rooftop Simplified Hydroponics Research Project 2002-3

Alternatives' Demonstration Garden, Montreal

Lettuce crop, Montreal garden

Simplified hydroponics garden in Columbia (ISH)

March 31, 2003

Submitted to:

IDRC – Canadian Partnerships Program
PO Box 8500, Ottawa, Ontario
K1G 3H9

Submitted by:

Alternatives
Action and Communication Network for International Development

3270 Ave du Parc, Suite 300, Montréal, Québec
H2X 2J1

Karen Templeton, Simplified Hydroponics Project Researcher

Alex Hill, Project Officer - Environment
(514) 982-6606
alex@alternatives.ca

Executive Summary

Alternatives embarked on a one year research project to investigate the potential of applying simplified hydroponics to establish rooftop gardens and urban agriculture in Montreal. Simplified hydroponics involves using light-weight growing media in place of soil, thus making gardening on rooftops feasible. Such types of urban agriculture hasve the potential to answer many of the problems facing modern urban centres such by strengthening food security, reducing the energy inputs for food production and distribution, and improving the urban environment.

The research involved three phases starting in May 2002 and ending in March 2003. The first phase took place in Montreal where a research garden was established to test the feasibility of the proposed techniques. Next the Alternatives' researcher spent three weeks studying at the Institute of Simplified Hydroponics (ISH) in Mexico in November 2002. Finally Alternatives collaborated with two student groups in Morocco to build and run two more research gardens. These phases brought together a wide range of international knowledge and experience related to the technical, social and organisational aspects of urban gardens using simplified hydroponics.

Overall the research garden and studies at ISH proved that simplified hydroponics can be adapted to Montreal rooftop gardens. It was concluded that further research is needed before nutrient broths can be developed entirely from compost, but mixtures of compost with animal bi-products (such as fish extracts) can be achieve high yields at an affordable cost. The research in Morocco showed the important role that student groups can play in adapting techniques to the local context and demonstrating the techniques to other community groups. Based on these results it was determined that simple-to-operate grower designs can be built of recycled material and used by community gardeners to establish simplified hydroponics gardens on rooftops in Canada.

1. Introduction

In January 2002 Alternatives initiated the rooftop simplified hydroponics project by bringing together a group of interested researchers and urban gardeners in Montreal. The initial goal was to identify ways to address environmental, food security and poverty issues related to Montreal's urban context. Through preliminary meetings the team recognised that light-weight options, such as simplified hydroponics, are needed to encourage widespread rooftop gardening.

In May of 2002, Alternatives assessed simplified hydroponics' feasibility in a small demonstration rooftop garden in the Petit-Patrie neighbourhood of Montreal. Over the following four months the garden was constructed and two rounds of lettuce and basil crops were grown using various nutrient solutions and root media. The researchers showed that natural nutrient solutions derived from fish extracts and compost combined with non-synthetic growing media (perlite, compost and straw) can significantly decrease growing times and increase yields when compared to traditional urban gardens. Moreover, it was proven that it is possible to construct and operate a light-weight garden cheaply by using recycled and recuperated material and watering by hand.

After proving the feasibility of simplified hydroponics in the Montreal growing climate, Alternatives continued to develop and refine the techniques in order to prepare for the 2003 growing season. In October 2002, Karen Templeton (the project's lead researcher) spent three weeks studying at the Institute of Simplified Hydroponics (ISH) in Mexico. From this experience new options for rain-water harvesting, nutrient mixing and root media were introduced to the program. The experience also opened the channels for an ongoing exchange of information between Alternatives' work in Montreal and other gardeners who are applying and developing similar techniques[1].

Following the collaboration in Mexico, Karen Templeton studied with local NGOs who were building two research gardens in Morocco, similar in design to the Montreal garden, during the winter of 2002-3. The research in Morocco provided further insights into the potential of simplified hydroponics in Canada by testing new crops and further options for nutrient broths and growing media were demonstrated. Moreover, this collaborative research assessed the feasibility for community groups to apply the simplified hydroponics techniques.

By combining the results of the three growing seasons, and collaborative investigations with other urban agriculture groups in Montreal, Alternatives has laid the groundwork to begin to apply rooftop simplified hydroponics on a larger scale in Canada. While the concept has been proven feasible and productive, the next challenge will be to work with community gardening groups, building owners and educational institutions to transfer the knowledge to the wider Montreal community.

---

[1] ISH and Alternatives have a network of SH partners in Mexico, Columbia, Senegal, Morocco and Nepal

Goal and Objectives

The primary goal of this project was to investigate the feasibility of using simplified hydroponics and other light-weight techniques to establish urban vegetable gardens in Montreal.

The objectives of the initial research were:

1. to establish a demonstration rooftop garden in Montreal as a testing ground for lightweight techniques such as simplified hydroponics;
2. to make links between knowledge obtained through research done in Canada on rooftop gardening and lessons learned in the developing world;
3. to gain hands-on experience using naturally-derived nutrient solutions to grow vegetables;
4. to develop methods of implementing rooftop gardens that are appropriate in Canada.

To meet the objectives, the following activities were undertaken:

1. simplified hydroponics systems, which use primarily waste materials for substrate, nutrient solution, and infrastructure were constructed;
2. the performance of these different systems was compared and the optimal combination of inputs for a given context was assessed;
3. the performance and feasibility of these systems was compared to conventional growing methods in the same context;
4. one researcher participated in a training course at the Institute of Simplified Hydroponics;
5. further research was done in collaboration with environmental groups working on simplified hydroponics projects in Morocco.

2. Explanation of Terms

- **Simplified Hydroponics**: Hydroponics is the growth of plants without soil, wherein nutrients are supplied in solution in the optimum concentrations for maximum growth, generally quadrupling yields that can be produced in the same space using conventional methods. Hydroponics also uses as little as one tenth of the water used in conventional agriculture, because water is not absorbed by the soil, and can be continually reused. The principal drawback to hydroponic production has been the need for complicated and expensive equipment for automated irrigation and monitoring, and the required expertise required to manage such equipment. However, recent projects in developing countries have shown that it is possible to build simplified hydroponics systems that use human labour instead of mechanical devices for watering and testing. It has also been shown that it is possible to use compost-derived nutrient solutions rather than commercially available chemical nutrient solutions. These systems result in reduced energy use, lower costs, and do not rely on a stable supply of electricity.

- **Urban agriculture** is an energy and resource efficient form of agriculture. It relocates food production where infrastructure, organic wastes, labour, and consumers are concentrated thus reducing transportation related energy inputs (Havana, Cuba currently produces a substantial portion of its food requirements within city limits, in response to a national shortage of petroleum[2]). Urban agriculture also tends to be less polluting because smaller scale production lends itself naturally to pesticide-free and fertiliser-free production. It offers a means of adapting to climate change and improving food security within cities, while simultaneously reducing the greenhouse gas emissions and other environmental stresses associated with food production.

- **Urban greening** answers many environmental problems associated with urban areas: reducing polluting urban rainwater runoff, absorbing greenhouse gases, and filtering airborne pollutants. Through the process of transpiration plants help reduce the urban heat island effect and thereby reduce smog levels and the energy used for air conditioning.

- **Growing on Rooftops** makes use of abundant, otherwise wasted space, thus overcoming the main barrier to widespread agriculture and greening in urban centres. Green roofs can increase the longevity of a building and reduce heating and (especially) cooling costs. In Montreal roofs are built to support up to 20lbs per square foot of snow in the winter. Hydroponics systems take advantage of this excess load-bearing capacity in the summer and can then be drained and dismantled in the autumn, thus avoiding adding extra weight to rooftops in the winter.

---

[2] According to government figures, in 1999 organic urban agriculture produced 65% of Cuba's rice, 46% of the fresh vegetables, 38% of the non-citrus fruits, 13% of the roots, tubers, and plantains, and 6% of the eggs: from personal communications Martin Bourque, Food First's Program Director for Sustainable Agriculture for the Oakland, CA-based Institute for Food and Development Policy/Food First

- **Water Reuse:** Irrigation water can be collected primarily through grey-water recycling and/or rainwater collection. The former helps to reduce the amount of wastewater to be treated as well as reducing the draw on drinking water supply systems. Rainwater collection provides an unpolluted source that can be stored and redistributed according to need. Its collection and use reduces the storm water runoff pollution shock caused when high rainfall events occur over areas with largely impermeable surfaces such as pavement and building roofs.

Research Methodology

The research was performed in three phases. The first phase (May – September 2002) involved building a research garden with 12 simplified hydroponics growers on a rooftop in Montreal. Two crops of lettuce and basil were grown in combined media (organic and inert) and fed by using organic nutrients. The second phase (October – November 2002) concentrated on researching the state-of-the-art of simplified hydroponics from around the world. To do this Karen Templeton participated in a three week training course with the Institute of Simplified Hydroponics where she was exposed to the results from research and applications in Mexico, Columbia, Senegal and Zimbabwe. The third phase (December 2002 – March 2003) entailed collaborative research with two rooftop simplified hydroponics gardens in Morocco. Here the results from the first two phases were assessed and new data was accumulated that will be applied to future projects in Montreal, beginning in the summer of 2003.

Description of the Simplified Hydroponics Techniques Used

Traditional hydroponics uses commercially produced chemical nutrient solutions in which the nutrients are all already in their inorganic form (i.e. they are available to plants). To adapt this system to use an organically-derived nutrient solution, some organic matter (compost) was added to the inert growing media. The function of the compost is threefold: to retain the solution for a longer duration, to provide the biological activity necessary to convert the nutrients to their inorganic (i.e. available) form; and to provide a nutrient reservoir which will buffer the more variable levels of nutrients in the organic solution. The goal was to determine which media (inert material + compost ratios) worked with which nutrient solution concentrations, trying to minimize the weight of the system and the labour required while maximizing yields.

Grower Construction and Watering

The growers were built from discarded 50 gallon olive drums (see picture below). The drum was cut at about 1/3 of its total height. The lower portion was then fastened to the lid of the drum with galvanised bolts. The upper portion was then fixed to a lattice of 2x8 lumber and recuperated insulation Styrofoam, and were used as the base for the growing basins. The basins were then attached to the base by tightening the lids back onto the drums. A spout and hose were fixed at the edge of each basin to allow for draining the basins. Finally a door was cut into the side of each base so that a nutrient storage bucket (a 20 l olive drum) could be placed inside, keeping it out of the sun.

Watering was performed once every one to three days, depending on the rate that the systems dried. Even if the plants were still wet after three days, due to rain for instance, watering was performed in order to replenish the nutrient supply in the basins. For each water, the spouts were closed and the basins were filled with nutrient solution up to a level equal with the top of the growing media. The nutrient solution was left for about 30 minutes to allow the media to become soaked thoroughly, then the spout was opened and the nutrient solution was allowed to drain back into the nutrient solution storage drums.

It is noted here that the system of 12 individual basins was used in order to isolate sets of plants such that different nutrient solutions and growing media could be used with minimal interactions that could skew the results. In community gardens other configurations could be used that hold larger numbers of plants and require less infrastructure.

Example of Montreal Grower Design

Phase 1: Montreal, Summer 2002

Round 1 (June – July)

This experiment compared yields of lettuce and basil from 12 combinations of 4 different media and 3 different nutrient-solution concentrations (see Appendix 1: experimental design chart). Each of the 12 treatments was applied to 7 lettuce plants and 2 basil plants, for a total of 84 lettuces and 24 basil plants.

The four media tested were: Perlite and peat 1:1 (control, no compost); perlite and compost 1:1; straw and compost 1:1; and straw and compost 3:1. The idea was to determine the minimum level of compost necessary, and also to compare the results from traditional commercially available media with a simple, cheap, biodegradable commodity. We had originally intended to use ground peanut shells as a media, but our source of shells was not able to supply our demand. A previous study in England tested several alternatives to rockwool and found straw to be the most effective.

The natural nutrient sources chosen were BioSea, a commercially produced mixture of algal extract and fish emulsion, which are two commonly used organic fertilizers. Three different concentrations were tested: strong, weak, and just water (control). The objective was to work towards finding the nutrient concentration that is necessary and sufficient for optimal growth – the control helped determine how much nutrient was being derived from the compost in the media. The nutrient content was calculated from the values indicated by the manufacturer and the dilution ratios. The level of dissolved solids in each solution was monitored using a conductivity meter, and samples were taken at the end of the experiment for more thorough laboratory analysis.

Plants were harvested 34 days after seeding (21 days after transplanting), and fresh weights of shoots and roots were taken, as well as leaf number, length, and, colour.

Observations: Round 1

- Organic content appeared to be too high in all media mixes tested, particularly in the straw mixtures, drainage was slow and did not allow for frequent application of nutrient solution.
- Both lettuce and basil grew larger shoots in the perlite mixes, the largest being in the perlite/peat/compost mix.
- Basil plants showed a fairly clear inverse relationship between root growth and shoot growth (i.e. The perlite/peat/compost mix grew the largest shoots and the smallest roots), suggesting that the media was providing sufficient access to water and nutrients so as to render additional root growth unnecessary and allow resources to be diverted to foliar growth. This effect was not seen with the lettuce, where root growth was more proportional to shoot growth. This was perhaps because the lettuce plants were smaller and their roots did not reach the depth at which there was sufficient moisture to render further growth unnecessary.
- The effect of nutrient concentration was less clear: Higher concentrations of nutrient produced smaller root growth in basil, but had no significant effect on basil foliar growth. In contrast, higher nutrient concentrations produced larger lettuces, but had a non-linear

effect on lettuce roots (.5% produced smallest roots, 0% produced the next largest and 5% produced the largest).

Round 2 (August-September)

This round tested a wider range of media with much reduced organic content (compost/inert material ratio) using two concentrations of BioSea, the same nutrient solutions as were used in round 1. There was also a conventional soil and water treatment for comparison in this round, using a mixture of a commercial potting mixture and compost.

The 6 media mixes used in this round were: perlite, peat and compost 12:1:1; perlite and peat 12:2; buckwheat husks, peat and compost 12:1:1; buckwheat husks and peat 12:1; straw and peat 12:2; Burlap, peat and compost (see Appendix 1). The two nutrient concentrations were 4:1000 and 1:1000. Each of the 12 treatments was applied to 9 lettuces and 2 basil plants, for a total of 108 lettuces and 24 basil plants.

In this round the lettuces were all seeded in a peat/compost mix at the same time, but then were transplanted at 2 different stages. Plants were harvested 49 days after seeding (45 days after the first transplanting), and fresh weights of shoots and roots were taken, as well as leaf number, length, and, colour. The growing time was extended to account for the shortened daylight hours during this round as compared to the first round.

Observations: Round 2

- Lower organic content in the media resulted in lighter pots and more frequent applications of nutrient solution.
- A two way ANOVA (presented in the appendix) showed significant effect of media type and solution concentration, as well as a significant interaction between the two.
- Regression analysis showed a significant correlation between shoot weights and shoot root ratios. That is, as in round 1, treatments with higher growth tended to have smaller roots in relation to their shoots.
- Plants grown in perlite grew far larger than those in any other treatment including conventional soil, and of those, plants given the stronger nutrient solution and just peat with no compost were the largest.
- Perlite with just peat (12:4) grew significantly larger shoots than perlite with compost and peat (12:2:2), and also showed a significantly larger shoot root ratio.
- Burlap was the second-most effective media used: plants grown in burlap outgrew conventional plants when given the strong nutrient concentration, but were comparable to conventionally grown plants when given the weak concentration.
- Conventionally grown plants outperformed both straw and buckwheat husks under both strong and weak nutrient applications, although the soil mixture used did not appear to offer optimal drainage, and so likely did not indicate the full potential of conventional systems.

See Appendices for numerical and visual representation of the data

Implications – Phase 1, Montreal

In the first round the nutrient solution concentration did not show a significant effect. Because plant-pot drainage was poor and watering infrequent, the solutions did not play a big role and instead the presence or absence of compost was most important.

In the second round the strong solutions produced significantly larger plants than weak solutions, indicating that the plants were obtaining most if not all their nutrients from the solutions. Perlite plants grown without compost present in the media mix were significantly larger than those grown with compost added. This could mean that the additional nutrients available in the compost raised one or more of the nutrients above its optimal concentration, or it could indicate a more complex interaction between the compost and the nutrient mix. Alternately the compost could have resulted in biological decomposition in the media which may have hindered plant growth. The fact that the higher compost ratios had a negative effect even with the weaker solution indicates that a simple overabundance of nutrient was not likely the cause of the negative effect. Thus it is most likely that the more complicated interactions were the cause of reduced yields with higher compost ratios.

The fact that more successful media and higher nutrient concentrations tended to have higher shoot/root ratios indicates that the improved growth was due to improved access to water and/or nutrients, and a consequently higher allocation of resources to shoot growth, which is characteristic of hydroponic culture. This underlies the importance of using media with high porosity and good drainage characteristics in simplified hydroponics systems.

Choice of substrate clearly plays a critical role in plant performance. Perlite was by far the most successful media tested, likely because it provided the best drainage. The use of biodegradable materials (and possibly high compost ratios) in the media mixture a poses the potential hazard of putrefaction, perhaps more so when using an organically-derived nutrient solution, and adequate drainage must be assured.

Moreover, the addition of compost to the growing media does not appear to be necessary for the absorption of organic nutrient, and may in fact inhibit drainage where it constitutes a significant proportion of the media mixture.

The watering technique may also have effected the results. For less porous media (such as burlap, straw or buckwheat husks) longer contact times between the nutrient solution and the media should be considered. 30 minutes was the typical contact time used here, but in some cases one hour may have been more appropriate. Furthermore, the systems were completely drained after water, instead it may be better to leave a 2-5cm reserve of solution in the bottom of the basin between watering.

The depth of the media may also play a role in preventing putrefaction and at the same time allow the roots to access water/nutrient reserves. Media depth should be determined according to the crop species, so that roots are just long enough to access a shallow reservoir of nutrient allowed to remain in the bottom of the container. In this case, media would be chosen to maximize drainage.

Overall it was demonstrated that it is possible to obtain high yields of lettuce and basil with lightweight simple hydroponics using only manual labour and organically-derived nutrients. Further research is need to assess other potential media substances, develop water-capture and re-capture techniques, methods for deriving reliable nutrient solutions from organic materials, and system designs which minimize weight load and required labour while maintaining high yields. From this phase of the research it was concluded that perlite/compost media provided the best results.

Phase 2: Studies at the Institute of Simplified Hydroponics

On-site training with the Institute for Simplified Hydroponics was done at a project site in Puebla, Mexico—October 15th to November 7th. The Institute of Simplified Hydroponics (ISH) was established in August 2001 in Tehuacan, Mexico, by Peggy Bradley and Jose Martin Atela Echevarria. The institute has both a national mandate, to use simplified hydroponics technology to address Mexico's poverty and hunger, and an international mandate, to foster similar programs in countries around the world. Here teachings focus on the simplified hydroponics techniques which have been developed by Peggy Bradley and others over the past 10-15 years in a handful of countries around the world.

The interests for this phase were to investigate structural considerations; the use of nutrients, water and media; garden management protocol; as well as considerations in training others in the technology and also in launching projects with community groups. Alternatives had access to a great deal of information and experience through ISH. Rather than documenting all that was covered in the trainings, the key points that contributed to Alternatives' research and ability to carry out future projects are presented bellow.

- In order to deal with the high sodium and mineral content of the water in Mexico, several measures have been taken: the garden has been run on half strength nutrient solution; before mixing the nutrient solution, water is treated with triple phosphate, which causes carbonates to precipitate out of the solution thereby reducing the total dissolved solids; once a week the garden is watered with collected rainwater only, to wash the substrate of mineral buildup; and there is a selection, both deliberate and inevitable, for plant species with a higher salt tolerance (eg. native local strains). Also, if a detailed water analysis is possible, the nutrient mix can be tailored to the mineral content of the water being used, avoiding the addition of minerals already present and thereby reducing the overall osmotic pressure and at the same time reducing the cost of the nutrient.
- When water has a higher than desired pH (i.e. above 7): sulfates used in nutrient mix can be replaced with chelates, which are available at a higher pH. Also, vinegar (weak) or triple phosphate (stronger) can be added to drop the pH, and/or peat can be added to the substrate. When pH is lower than desired, baking soda can be used to raise it, and/or plants with lower pH tolerance range can be grown (eg. Tomatoes).
- Being automated, commercial hydroponic systems have been able to provide continuous flow of full strength nutrients to plants, thereby maximizing growth rates. What is sacrificed in such systems is flavour and nutrition, as it is during a period of nitrogen scarcity than nitrates are converted to vitamins, and that sugars build up in the plant tissues. This process is known as "sugaring up", and is also a good reason not to overdo the quantity of nitrogen in the nutrient solution, particularly just prior to harvest. With very high nitrogen levels what one gains in quantity one sacrifices in quality.
- Organic hydroponics have been practiced with success in various parts of the world. The advantages of organic nutrients are mainly with regard to cost, availability, and waste-

management. It also tends to produce heartier plants that can survive better in adverse conditions and have a longer shelf life. The disadvantages are with regard to both performance and safety: making a reliable nutrient solution using organic materials is trickier and it can be difficult to achieve high enough levels of nutrient, of nitrogen in particular; in order to achieve high enough levels of nitrogen, animal sources are generally required, and these generally entail some level of risk of pathogenic or chemical toxicity. The use of organic nutrient also brings with it a greater likelihood of contamination with moulds, fungi and bacteria.

- In order to achieve high enough nutrient/nitrogen content for a complete hydroponic nutrient, worm castings provide a good base (higher in N than regular compost), to which can be added blood or bonemeal, fishmeal, bat or bird guano, or some other composted animal waste (sources should be well-investigated and if possible analysed for possible safety hazards). Other interesting possible sources include hair, horns and fish-water (ie. aquaponics).
- By being able to see, mix and work with the substrates which are being used at ISH, Karen was able to develop a sense of what would work well and what would not. It was also possible to learn to avoid many of the problems that have already been solved at ISH, including rotting of organic substrates (solved using solar sterilization and fermenting techniques) and presence of too much powder in volcanic rock supplies (solved by screening for particle size).
- Pest species have been dealt with using traditional organic methods, including yellow and blue cards, garlic sprays, milk sprays, etc, and also by encouraging the growth of wild species that host predator-insects, such as Umbelliferae species, calendulas, bergamot, brassicas, vetches, etc.
- It was also possible to investigate other options for alternate agricultural systems at ISH such as Fertigation, the use of drip irrigation with hydroponic nutrients. This technique has been developed and used extensively in Israel, and is being investigated for use in Mexico now as well. The idea is to render infertile land productive using a minimum of water and fertilizer. The main potential problem with this technology is salt build-up and consequent soil and water contamination. Unlike traditional closed-system hydroponics, fertigation does not recapture spent nutrient solution, which instead drains into waterways and leaves a build up of unused salts in the soil. The possibility of containing the waste using layers of plastic or hard packed earth is a possibility currently being considered in Mexico.

It is also noted that ISH has developed a 100 page manual in English and Spanish, as well as many other educational materials that can be obtained on CD-ROM through the ISH website: www.carbon.org/

Phase 3: Collaborative Research in Morocco

The final phase of the research was completed in collaboration with two groups who have built and operated simplified hydroponics rooftop gardens in Morocco. Through this collaboration Alternatives worked with Faculty of Biology and Club Helios at the University of Casablanca, and the with the Club d'Environnement at the Lycée Hassan II, a high school in Rabat. The groups worked in cooperation to find appropriate spaces, to build new gardens and grow research crops.

Casablanca Garden — Faculty of Science, The University of Casablanca: The Helios Club is affiliated with the Association d'Enseignants de la Science de la Vie et de la Terre (AESVT) an association of science teachers who initiate and develop environmental projects throughout Morocco. In addition to the students in the club and its faculty representative, Professor Fougrach Hassan, a small team of interested professors has participated in the project adding expertise in the fields of plant physiology, water and soil analysis, and agronomy.

The garden in Casablanca has ten growers, five constructed of plastic-lined wooden frames and five constructed from truck tires according to a local method of bucket production. In order to maintain consistency with the data accumulated in Montreal and in the other Moroccan garden, the team decided to concentrate on lettuce production. Over all they have planted approximately 150 lettuces, which at the time of writing had not yet been harvested.[3]

Rabat Garden — Ecole Lycée Hassan II : The Club d'Environnement is run by a teacher involved with AESVT. In this project there is also a small team of teachers who have begun to participate – mainly members of AESVT from different schools who would like to bring the project to their own schools.

The Lycée researchers opted to construct six floating-bed growers, supporting in total 60 lettuce plants and ten mint plants. These growers are made from purchased plastic bins (l:w:d 75cm:50cm:50cm). They differ from the growers used in Casablanca and Montreal because the water is not drained from the growers each day. Instead the plants and a small amount of substrate are suspended in a floating matrix (such as a plank of Styrofoam with holes bored at even intervals) which sits upon a reservoir of nutrient solution approximately 40cm in depth. The roots are thus submerged in the solution, which is topped up occasionally.

This configuration is simpler to maintain, but presents some complications related to maintaining an adequate supply of oxygen to the plant roots. In conventional hydroponics aerators are used to keep the water saturated with oxygen, however for simplified hydroponics aeration is done through a combination of hand agitation and ensuring that an adequate contact area between the water surface and the air is maintained.

Experiments underway

Thus far the students have built the infrastructure and begun experiments that will compare 4 substrate mixtures—perlite and wood shavings, gravel and wood shavings, crushed brick and wood shavings, and gravel with wheat hulls—as well as floating-beds and conventional (soil) culture. The experiment will also compare results from beds made from tires with those made from wood. The main crop being grown is lettuce, chosen for its fast growth and higher

---

[3] Because the Morocco research took place during the winter-spring growing season where average daily highs range from 12C to 20C, time needed for the vegetables to mature was significantly longer than was experienced in Montreal during the late summer where temperatures are warmer.

turnover in the experimental phase. The students have begun working with worms for composting, and have been collecting rainwater for use in the nutrient solution. They have performed laboratory analyses of the water and nutrient mixtures.

Both gardens are investigating the same substrates and nutrient solutions, such that the results can be compared. The nutrient solutions are prepared from the premixed powders obtained at ISH in Mexico. These differ from the solutions used in Montreal as they include both natural and chemical nutrients. It is expected that once the gardens are well established the researchers will begin to replace the premixed nutrient powders with locally available materials such as compost, animal wastes and fish extracts.

In order to avoid salt build-up problems, and take advantage of the compost added to the growing media, the growers are supplied with nutrient solutions mixed at half the maximum allowable strength (as is done at ISH). In Casablanca one grower has recently been established that uses full strength nutrient solution in order to assess the difference in the yields versus nutrient inputs. It is expected that the cooler temperatures during the winter and spring might facilitate the use of stronger nutrient solutions (due to slower evaporation rates). However, a cautious approach has been taken regarding nutrient strengths due to high mineral concentrations already in the feed water. At the time of writing however, no data on plant yield is available because the plants have only reached an early stage of development.

The difficulties the groups had obtaining substrates and building the gardens has also delayed obtaining results from the garden itself as the plants have not yet completed their growth. Furthermore, in some cases organic materials have grown mould upon becoming wet. Solar sterilization techniques are being looked into, as well as oven sterilization.

Social and organisational implications

Both gardens in Morocco are clearly research facilities, not yet community gardens. It was deemed most appropriate to work with students because they have an excess of free time, an interest to learn and can apply the results to their academic studies. It was decided by the researchers in Morocco that until the techniques have been adapted and proven by the students it would be best not to involve community groups in case the groups became discouraged if some of the experiments proved less than successful. A full year of experimentation is planned before the techniques will be ready for diffusion to the interested community groups, of which there are many.

Karen Templeton cooperated with the two student groups as they established the projects, recruited gardeners and researchers, built the gardens and grew their first set of crops. The search for growing media proved to be a bigger challenge to the groups than was anticipated, as none of the substances that have proven successful in other countries are readily available in Morocco. Thus searching for and testing suitable substrates was the primary focus of the Moroccan groups' first research phase. The groups anticipate that results of testing alternate nutrient sources will come later.

Interestingly an artisan who manufactures waterproof basins out of old tires was identified in Marakech. Some of these basins were brought to the garden and the technique for building the basins was shown to people in Casablanca and Rabat who are involved in the informal economy. It is expected that if these basins prove safe for vegetable production that the demand for these basins will grow, demonstrating the potential for spin-off economic benefits from simplified hydroponics gardening.

At the Lycée, Karen would meet once or twice a week with the students and usually at least one teacher. At each meeting they would assess what needed to be done next and assign tasks. Building and planting was generally done together in one large group, whereas finding materials/supplies/tools was done individually or in groups of two. Daily maintenance (watering and oxygenating) was at first haphazard and largely fell to Karen, but later on students were assigned responsibility for a given day of the week and a chart was posted on which they were to report what they had done and the status of the plants, etc.

In Casablanca, the students constructed the garden themselves, determined the data collection and watering protocols and did their own planting. Karen would meet with the garden leaders once every week or two to obtain reports on their progress and offer suggestions to overcome difficulties that they were having. The Casablanca research has shown the promise for local researchers to quickly understand and apply simplified hydroponics, with a minimal degree of outside guidance.

The most important lessons learned from this phase of the research relate to the organizational and tactical elements, which can be observed by comparing the difference in the performance at the two project sites. The University project has been by far more successful than that of the Lycée, due to two main factors: the fact that it is located at a research institute and therefore has better access to resources (intellectual as well as material); and the independence and initiative of the students involved. This independence is due in part to necessity, as the University team has received less guidance from Alternatives.

In contrast, at the Lycée, where not a move was made without the direction of Karen, the students' enthusiasm has not translated into the same ownership of the project. As a result, the sustainability of this garden is unclear. Due to problems the students had maintaining the research protocol at the Lycée, it was decided in the end that it would best to maintain this facility mainly as a demonstration garden rather than a research site.

Thus, this experience has underlined the importance of adapting the type of research to the abilities of the partner(s), and specifically the need for a research facility to be involved in the experimental phase of the project. It also helps to define the fine line between providing adequate support and taking total responsibility when working in a temporary capacity with local groups.

A major achievement of this research has been the mobilization of various bodies that are interested in engaging in the preliminary research, as well as the introduction of the idea to various associations which will then be ready to take on the project once the basic techniques have been established. Once a basic functioning technology has been developed, there will be no shortage of associations interested in participating—links have been made with women's groups, youth groups, community development projects, and schools, all of whom have expressed a keen interest. This has shown the promise of urban gardening as a system to encourage broad-based involvement in food-production, which will likely be observed in Montreal now that simplified hydroponics has been proven there.

Interestingly, Morocco's current agricultural policies run counter to global trends in their emphasis on self-sufficiency and food security, and thus the state is more likely than most to support initiatives that encourage small-scale agricultural operations. Even more important, however, is the relatively recent emergence of a non-government sector, which addresses social and environmental issues and works independently of state agencies. The idea of an active citizenry is still relatively new here and the associations that have arisen seem eager to take advantage of this opportunity to mobilize and engage in public debate and action. There is also an openness to collaboration between different types of organizations, a recognition that the issues of poverty, environment, health, education, and human rights are all related and that a variety of approaches and strategies will be necessary to address all these issues that concern them.

Implications for Canadian Gardens

The implications of this research for applying simplified hydroponics in Montreal are extensive. First, new options for building affordable growers have been found, as well as new types of growing media that can be used. Also, it has been shown that with some basic information gardeners can easily switch back an forth between organic and chemical nutrient sources depending on availability. Finally, different grower configurations (such as floating beds) have been tested giving the researchers access to a wider range of experience.

Concerning the organisational aspects, the Morocco research has pointed out some of the difficulties and benefits associated to working with student groups. Students offer an excellent target group for these project due to their enthusiasm and the fact that they will have many years ahead to apply the skills and knowledge they gain. This research has shown that a balance must be made between guidance and control, so that the students will feel and ownership over their research. In Canada, research gardens could be established for summer science students, or for students who have a specific interest in horticulture.

Finally this phase has shown how to approach community groups to get them interested in establishing their own gardens. The successful demonstrations at the high school and university have become catalysts for widening the interest in the project. When other community groups have visited the gardens, they have themselves become enthusiastic over the potential for simplified hydroponics in their community.

Future Research

While this project has proven the technical feasibility of using simplified hydroponics in Montreal, further research and application of the results is needed before simplified hydroponics will be applied widely in Canada. The next step will be to establish a larger garden in Montreal, during the summer of 2003, at a high profile location, in cooperation with a team of community gardeners. This garden will provide an opportunity to test other configurations that are simpler to build and operate. Also there is still a need to combine in-house composting techniques with media mixing and nutrient solution development. Finally, this garden will be large enough to allow for the trianing of more people in the techniques and its profile will help to publicise the potential of simplified hydroponics in Montreal and across Canada.

After a larger high profile garden is established, the work in 2004 and 2005 will then focus on designing simplified hydroponics start-up packages, including a pre-fabricated grower, nutrients, media, seeds and an operation manual, to be distributed to school groups, community garden groups and interested individuals. This the garden established in 2003 will act as a training, research and distribution centre and the other participants will be invited to submit their results and observations to the research team to further extend the scope of the investigation.

Conclusion

The results of this research project have shown that it is feasible to use simplified hydroponics to establish urban gardens in Montreal, and that these gardens can take advantage of their light weight to be placed on rooftop. In Mexico, it was found that an international calibre institution is available to assist groups seeking to adapt the technology to their own environment. Finally, the research in Morocco demonstrated the important role that students can play in establishing demonstration gardens and performing local research. It was also observed that these gardens can be used to promote the idea to other community groups in the area.

These three elements form an important first step to establishing simplified hydroponics in Montreal: they demonstrate the technical feasibility, the availability of the necessary background and support, and the ability of student groups to introduce the concept to the wider community. Upon this solid basis, Alternatives will continue to promote simplified hydroponics gardening in Canada.

Acknowledgements

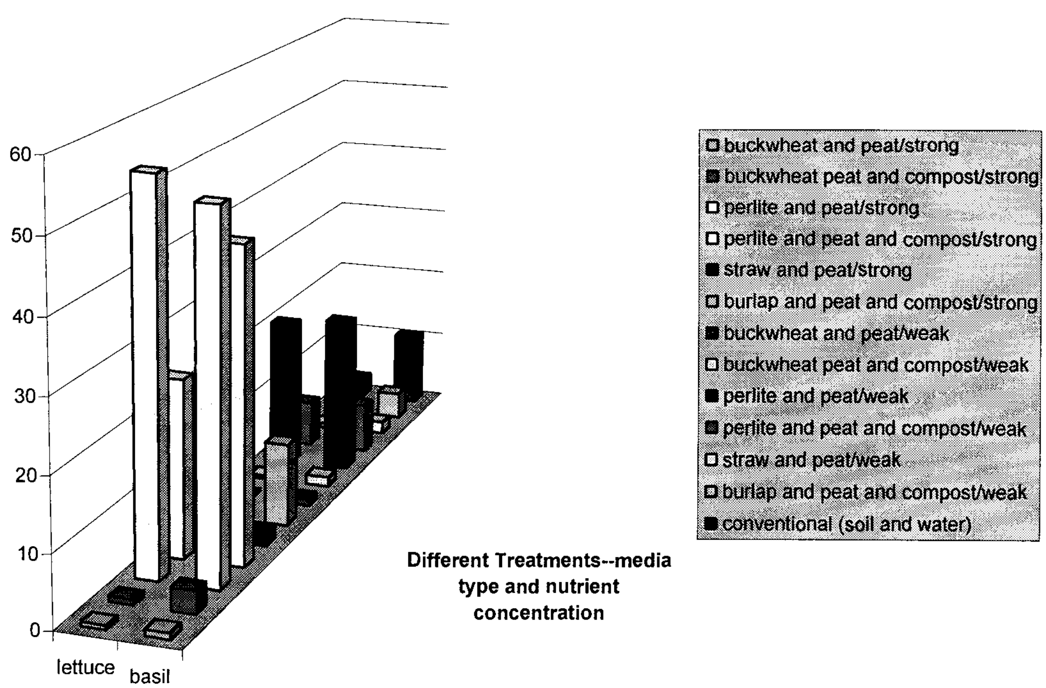
Alternatives would like to express its sincerest thanks to the IDRC, without whose financial assistance the project would not have been possible. We would also like to extend thanks to all of our partners who collaborated on the research. The knowledge and experience that these groups brought to the research greatly expanded the depth and breadth of the findings. Thanks go out also to Prof. Robert Kok of McGill university who provided sound scientific guidance to the project. Finally we would like to thank a number of fiends who contributed to the work in Montreal by helping to host and maintain the garden, including: Jan Kubanek, Mike Diter, Ellie, Jon Soehl and Claire Henan.

Financial Report

Table 1: Project Expenditures June 2002 – March 31, 2003

Item	Description	Amount
Project Leader	Salary Karen Templeton June-November 2002	$6,000
Coordination	Salary Alex Hill June-November 2002 (1/4 time)	$4,289
Per diem	Karen Templeton (Morocco) December 2002 – March 2003	$3,945
Travel	Canada – Mexico Canada – Morocco (50%)	$1,473
Honoraria	Garden Assistant (Montreal) AESVT (Morocco)	$721
Communications		$29
Materials	Garden Construction (Montreal)	$988
Training	ISH Mexico	$555
Administration		$2,000
Total		$20,000

Comparison of Fresh Shoot Weights of Various Treatments with Conventionally Grown Plants



Appendix 1: Montreal experimental design chart

Table A1: Round 1 Results

Substrate	**Nutrient Solution**	**Replicates**	**Mean shoot weight (g)**
Perlite and peat 1:1	water	7 lettuce 2 basil	1,5

Appendix 1: Montreal experimental design chart

Table A1: Round 1 Results

Substrate	Nutrient Solution	Replicates	Mean shoot weight (g)
Perlite and peat 1:1	water	7 lettuce 2 basil	1,5

12,9

Biomer 1:200

7 lettuce

2 basil2,17,4Biomer 1:20007 lettuce

2 basil3,76,3Perlite and compost 1:1water

7 lettuce

2 basil4,07,5Biomer 1:200

7 lettuce

2 basil4,45,7Biomer 1:20007 lettuce

2 basil5,29,2Straw and compost 3:1Water 7 lettuce

2 basil2,114,4Biomer 1:2007 lettuce

2 basil1,511,8Biomer 1:20007 lettuce

2 basil2,86,5Straw and compost 1:1Water7 lettuce

2 basil0,59,0Biomer 1:200

7 lettuce

2 basil0,413,5Biomer 1:20007 lettuce

2 basil0,46,5

Total number treatments: 12

Total number of lettuce plants: 84 (36 of which are 3 to a pot, and 48 are 2 to a pot)

Total number of basil plants: 24

Total number of basins: 12

Table A2: Round 2 Results

SubstrateNutrient solutionReplicatesMean shoot weight (g) Buckwheat husks and peat

6:2

4:10009 lettuces

2 basil0,60,91:1009 lettuces

2 basil0,40,9Buckwheat husks and peat and compost

6:1:1 4:10009 lettuces

2 basil0,73,11:1009 lettuces

2 basil0,51,3Perlite and peat

6:1:1

4:10009 lettuces

2 basil54,250,91:1009 lettuces

2 basil20,821,9Perlite and peat and compost

6:24:10009 lettuces

2 basil24,643,71:1009 lettuces

2 basil6,36,8Straw and peat

6:2

4:10009 lettuces

2 basil2,11,91:1009 lettuces

2 basil0,51,7Burlap (40”X40”)

peat (2 cups); compost (1cup)4:10009 lettuces

2 basil3,911,41:1009 lettuces

2 basil0,73,7Total number of treatments: 12

Number of lettuce plants: 108 (3 per pot, 3 pots per basin)

Number of basil plants: 24 (2 per pot, one pot per basin)

Total number of plants: 132