# SIMPLIFIED HYDROPONICS TO REDUCE GLOBAL HUNGER

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## Abstract

According to the United Nations Food and Agriculture Organization (UN FAO), more than 800 million people do not have enough to eat. Simplified hydroponic technology offers the potential of reducing hunger. This technology has been explored since 1984 in Colombia, and introduced in 13 countries with projects supported by UN FAO, United Nations Development Program (UNDP) and others. The technology reduces land requirements for crops by 75% or more, and water use by 90%. Crop nutrients are contained and recycled so no residual salts are lost to environment. Herbicide use is non-existent and pesticides required are natural vegetable sprays and barriers. Bed growers of $2m^2$ can be built for material costs of \$6.42 per $m^2$. Common production figures for simplified hydroponics range from .11 to 0.23 kg of edible food per $m^2$ per day. Data from Colombia show a $40m^2$ garden can produce an income of \$101.00 per month when planted in commercial crops. Costs and profits are summarized for basil, celery, pepper, lettuce, cucumber, radish and tomato. Profits range from \$5.28 (US) per $m^2$ per year for cucumber to \$40.26 (US) per $m^2$ per year for lettuce. Production ranges from 8.8 kg/$m^2$ per year for cucumber and 64.9 kg/$m^2$ per year for lettuce.

## 1. Introduction

According to the UN Food and Agriculture Organization, in 1999 an estimated 800 million people live a day to day existence of not having enough to eat. There is a present need for more food production, or food production that reaches the people who need it.

Many of the 800 million people in need live in areas where solar resources and annual rainfall are sufficient to produce vegetable crops. The majority of humans requiring food live in the tropics, often in areas with solar resources sufficient to grow food year round.

Simplified hydroponics is a technology incorporating soilless culture techniques without the use of mechanical devices or testing equipment. All hydroponic nutrient is hand poured over plants once in the morning, or supplied in floating beds that are hand aerated twice a day. The only energy requirements for garden operation are natural sunlight and human labor.

According to UNDP, in Colombia, simple hydroponics generate approximately \$30.00 per month on 10 $m^2$ and require one hour of daily care. Up to two monthly minimum salaries (US \$90-\$180) can be made on 30-60 $m^2$ of planting (UNDP, 1996).

Simplified hydroponics was developed in the early 1980's in Colombia. It was adapted as a method of helping urban poor in Jerusalen outside Bogota feed their families and provide supplemental income. In Jerusalen, over 120 women participated in establishing gardens. Donated wood pallets were converted to bed growers, rice hulls (an agricultural byproduct) was donated for media and inorganic commercial hydroponic nutrient was supplied. Produce was purchased by a local supermarket. Within 60 days of project initiation, several participants were making two to three times the monthly income of their semi-skilled husbands (UN FAO, 1996). The gardens also supplied fresh vegetables

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for the family.

Since the original Jerusalen project in 1984, projects have been implemented in 13 Latin American and African countries, mostly funded by UNDP and UN FAO. A few projects have also been developed by non-profit NGO's such as Institute for Simplified Hydroponics project in Zimbabwe (Jefferson, 1999). A summary of the projects spanning over a decade with dates and funding sources are included in Table 1.

## 2. Materials and Methods

Simplified hydroponics has evolved to be accessible to people with limited resources. For this reason it is optimized to utilize minimal inputs of land space, water, nutrients, and grower infrastructure. UN projects have evolved a technology that incorporates low inputs and concentrates on utilizing recycled materials, or agricultural wastes (Marulanda *et al.*, 1993; Marulanda, 1999; Bradley *et al.*, 2000).

### 2.1. Equipment

Hydroponic growers are built of local materials such as recycled or salvaged plastic containers, tubs and buckets, or bamboo tubes and pots. Plastic bags and sheeting is also used to waterproof discarded wood pallets or bed growers built of lumber. A simplified grower of two $m^2$ of growing space requires from \$9.00 to \$12.50 to build (Marulanda *et al.*, 1993). This cost can be reduced if local bamboo is used instead of milled lumber.

### 2.2. Growing substrate

Growing substrates include sand, peat moss, volcanic materials and surplus agricultural products such as rice hulls. There are no manufactured or altered substrates required, so there is no energy cost other than obtaining and transporting the substrate.

### 2.3. Nutrients

Nutrients used in simplified hydroponics include both inorganic nutrients traditionally used in commercial hydroponics, and organic nutrients made of locally available materials such as bat guano and worm castings. In all cases, excess nutrient is recycled into the growers so no nutrient is allowed to runoff to the environment, and all nutrient is used for plant production.

### 2.4. Energy

All simplified hydroponics requires hand pouring nutrient water over growers once a day, or twice a day hand aeration of the floating bed growers. Since the growers are placed outside, there are no lights required to increase daylength or growing season. Environmental control is provided by shade cloth, exterior garden landscaping, or hand built shelter to retain moisture in arid climates.

### 2.5. Water

All water used in hydroponic culture is applied to the bed grower and then excess is gathered below and recycled to growers the next day. Careful choice of media minimizes surface evaporation and retains moisture in the root zone. Average water use for growers is from 2 to 4 liters a day per $m^2$ for 0.11 to 0.23 kg produced, (0.5 to 1 gallon per 0.25 to 0.5 pounds).

Hydroponic culture, if maintained at 0.11 to 0.23 $kg/m^2$, represents a reduction in water use from 5 to 10% of that required for soil. UNDP reported hydroponic farming is highly efficient, using 1/10$^{th}$ of water required for field crops (UNDP, 1996).

Currently, approximately ½ of the earth's accessible fresh water is being utilized, with a substantial portion being used for irrigated agriculture. Agriculture use in general uses 65% of the accessible fresh water (Postel, 1992), and simplified hydroponics could reduce requirements for this resource.

2.6. Land

Simplified hydroponics, when diligently applied, can produce four times the amount of food produced in a similar amount of soil based surface area. Because the growers can also be placed in advantageous areas and covered with shade cloth, growing conditions can be improved or extended. Simplified hydroponics uses about 25% the land required for soil based crops.

2.7. Pest Control

In simplified hydroponics, pest control is maintained by physical barriers, natural sprays of garlic and hot pepper, and diligent inspection. This can be a substantial savings from the pest control costs of soil based crops. In Thailand, in 1991, estimates of commercial soil based vegetable production costs for chemicals to control pests and diseases ranged from 15-56% of total crop costs (DOAE, 1991).

2.8. Transportation

Globally, transportation and the use of vehicles and fossil fuels to deliver food to consumer often requires more BTU's of energy than that contained in the food. In simplified hydroponics, the food is raised on site for the family, removing the cost of food delivery and reducing the energy required to obtain food. When food is marketed, due to the small quantities, it is often sold to consumers nearby.

2.9. Food Security

Current circumstances on earth make much of the human population dependent upon fossil fuel for production and delivery of their food supply. This dependency is particularly troubling considering that fossil fuel reserves of the earth are expected to be severely depleted by the year 2050. At this time the earth's population is expected to increase from 9 to 15 billion people. The requirements of soil based agriculture for water and fossil fuels may outstrip mid century supply. Clearly food production alternatives should be carefully considered.

## 3. Results

Home gardens utilizing simplified hydroponics have taken two basic forms. One is a garden producing foods for the family, called the Sustenance Garden and a garden designed to increase family income, called the Minimum Family Economical Unit.

Two types of simplified growers are used in the Armenia, Colombia UNDP project. Each bed grower is constructed with recycled lumber, lined with plastic liner and either filled with media or used with a Styrofoam sheet for a floating bed. Each wood 2m$^2$ grower with media made with recycled wood is estimated to cost \$12.84 (6.42 m$^2$) in US dollars, and expected to last two years. When used as a floating bed grower the cost is reduced to \$11.92 (5.96 m$^2$). The complete garden of 20 bed growers (40m$^2$) costs about \$256.54 to build and fill with media (Table 2).

Simplified hydroponic gardens have been tested in 13 countries. These gardens have consistently produced high quality and fast growing produce. Principle crops grown include lettuces, tomato, bell pepper, basil, celery and radish (Marulanda, 1999). In data gathered from the recent Armenia, Colombia project, results of garden productivity are averaged and estimates of commercial values are obtained (Table 3).

The estimated productivity of the simplified hydroponics of 0.11 to 0.23 kg of wet weight produce per $m^2$ day compares with literature estimates for many hydroponic systems. The 0.11 kg per $m^2$ was reported for potato, carrot, sweet potato, turnip and radish in pioneer hydroponics experiments in 1936 (Gericke, 1949). Current commercial hydroponic operations routinely report from 36 to 64 kg/$m^2$ year for tomatoes.

### 3.1. Sustenance Garden

Some of the home gardens have been designed to provide essential foods for the family. A 20 bed grower garden, (40$m^2$) can be planted in vegetables such as potato, carrot, green beans, lettuce, tomato, bell pepper, etc. These foods are not grown for their commercial value, but for family food supply.

A 20-bed garden can produce about 1500 calories a day, and add to family nutritional comfort. The sustenance garden can provide daily minimum fresh foods, vitamins and minerals, but is not yet useful in providing daily staple foods such as dried beans, corn, rice or wheat. Staple foods can also be grown in hydroponic culture, but early trials are still not cost effective. Cereals are often only 15% edible, and so the nutrient costs can be more than the value of the crop (Jefferson, 1999).

### 3.2. Family Economical Unit

A Family Economical Unit of 20 bed growers (40 $m^2$) requires up to 40 gallons of water a day, and costs from $3.60 to $5.80 per month in nutrients. This home garden is designed to produce crops that produce the highest income. Data from Colombia estimate a garden produces about $101.00 per month (Table 3) if planted in crops that are sold for family income. Profits range from $5.28 (US) per $m^2$ per year for cucumber to $40.26 (US) per $m^2$ per year for lettuce. Production range from 8.8 kg/$m^2$ yr for cucumber and 64.9 kg/$m^2$ yr for lettuce (Table 4). This garden requires four hours of work a day, and provides a minimum living wage for a resident of Colombia.

The Colombia project is at $4^0$N latitude and enjoys year round sun and weather that is conducive to garden growth. Colombia estimates of both growth and value would be different for other climates and cultures.

## 4. Discussion

There are many needs for research to support simplified hydroponics. Very little research has been completed on the nutritional value of food produced in simplified hydroponics. While crops are consistently of high commercial value due to freshness, flavor, color and appearance, there is little information on actual food value. Questions remain as to the nitrate and vitamin C content of hydroponic produce under different nutrient regimes (Blanc *et al.*, 1980; Vogtmann *et al.*, 1996).

Hydroponic produce produced with supplemental trace minerals for human health offer potential to reduce human disease and suffering. Recent hydroponic experiments utilizing selenium-enriched garlic have shown a substantial reduction in cancer risk associated with ingesting garlic grown in soilless culture with excess selenium (Ip *et al.* 1992). This and other research pertaining to the potential health benefits of trace minerals supplied in hydroponic food offer research opportunities for simplified hydroponics and the health industry in general

Optimized root zone conditions can maintain high productivity by ensuring a refreshed air supply of oxygen for efficient air exchange. The insulation properties of growing media can also protect plant roots from some temperature extremes.

Appropriate choices of growing media may increase garden productivity. Natural growing media such as volcanic materials like pumice can be utilized along with mixtures of rice hulls or other organic agricultural wastes (Mackowiak *et al*. 1996). Mixture such as these provide a use for some underutilized materials. Research needs include testing mixtures in arid climates with additions such as sawdust to enhance moisture retention (Rankin, 1980).

Staple crops need to be tested in simplified hydroponic growers. Smaller day neutral soybeans, shorter wheat and other crops may aid in reducing the space required for staple food crops in simplified hydroponics.

Organic nutrients such as fish waste water, worm castings and bat guano should be tested in simplified hydroponics to aid in developing organic nutrients that can be manufactured at home. Household wastewaters might used for non-food crops such as flowers (Schwarz, 1995). The experiences in establishing simplified hydroponics over the past decade have also determined problems with ensuring the technology is successful. Urban area projects in particular have suffered from availability of nutrients (UNDP, 1996).

Training materials and training methodologies need to be developed into curriculums and perhaps credentials to begin a larger scale project to train more people in simplified hydroponics technology. Training materials should be sensitive to some impacts of hunger and poverty including illiteracy. Training materials and methodologies need to be adapted to benefit and strengthen local customs and culture rather than supplant.

Simplified hydroponics is a technology that can help people feed themselves and perhaps begin a small cottage industry. It can be established utilizing conservation methods that reduce water and land requirements for vegetable production. By recycling nutrients used in hydroponic culture no excess fertilizers are released to the environment thus the technology reduces the potential runoff pollution of soil based agriculture. By utilizing human labor throughout the production process, requirements for fossil fuels of soil based culture are eliminated.

Simplified hydroponics can be utilized to reduce global hunger. The potential of this technology may extend to well over 800 million potential users. While original research and trials over the past decade have established a base for the technology, much work is needed to continue to educate and provide information to those most in need.

## References


Blanc D. and Triboi-Blondel A.M., 1980, Influence of nitrate content in the nutrient solution on yield and nitrate content in eggplant (*Solanum melongena*), ISOSC Proceedings, ISOSC, The Netherlands:143-147.

Bradley P., 2000, Bringing Hydroponics to Senegal, Growing Edge, New Moon Publishing, Corvallis, OR. 11(3):62-71.

Bradley P., 2000, Fast Food Relief. Practical Hydroponics and Greenhouses, Casper Publications, Sydney, Australia 51:73-81.

Bradley P. and Marulanda C., 2000, Home Hydroponic Gardens, Institute of Simplified Hydroponics, Corvallis, OR.

DOAE, 1991, Growing vegetables without toxic chemicals residue, Department of Agricultural Extension (DOAE), Bankok.

Gericke W. F., 1949, A Complete Guide to Soilless Gardening, Prentice-Hall, New York.

Ip C, Lisk D., Stoewsand G.S., 1992, Mammary Cancer prevention by regular garlic and selenium-enriched garlic, Nutrition and Cancer 17:279-286.

Jefferson E., 1999, Thriving on a Survival Garden, Growing Edge, New Moon Publishing, Corvallis, OR 10(6): 44-55.

Mackowiak C.L., Garland J.L., and Sager J.C., 1996, Recycling Crop residues for use in recirculating hydroponic crop production, Acta horticulturae 440:19-24.

Marulanda C. and Izquierdo J., 1993, Popular Hydroponic Gardens, FAO Regional Office for Latin America and the Caribbean, Santiago, Chili.

Marulanda C., 1999, Hidroponia Familiar, Proyecio Nacional Hidroponia, El Salvador.
Postel S., 1992, Last Oasis, Facing Water Scarcity, W.W. Norton Co, New York p. 19.
Rankin J.B., 1980, The use of Sawdust as a Growing Medium for all crops in Grow Box Beds in Central Africa, ISOSC Proceedings, ISOSC, The Netherlands:385-390.
Schwarz M., 1995, Soilless Culture Management, Springer-Verlag, New York p 107.
UNDP, 1996, Urban Agriculture, Food, Jobs and Sustainable Cities, New York p 26, 119.
Vogtmann H., Matthies K., Kehres B. and Meier-Ploeger A., 1993, Enhanced Food Quality: Effects of Composts on the Quality of Plant Foods, Compost Science and Utilization 1:82-100.
Zapp J.G., 1991, Cuiltivos sin tierra, Hidroponia Popular, Proyecto Regional para la Superacion de la Pobreza, Bogota.

Tables

1. Projects and field trials of simplified hydroponic gardens including dates and project funders.

| **Location** | **Date of Project** | **Project Funder** |
|---|---|---|
| Belize | 1997 | UNDP |
| Chile | 1992 | UNDP & FAO |
| Colombia | 1986, 2000 | UNDP |
| Costa Rica | 1990 | UNDP, INCAP and Spanish cooperation |
| Dominican Republic | 1990 | UNDP |
| Ecuador | 1992 | UNICEF |
| El Salvador | 1991 | UNDP |
| Guatemala | 1996 | World Food Program (WFP) |
| Nicaragua | 1993 | UNDP |
| Peru | 1993 | FAO |
| Senegal | 1998 | FAO Rome |
| Seychelles | 1998 | FAO Rome |
| Venezuela | 1990 | UNDP |

2. Materials cost for hydroponic bed growers, both for media and floating beds per m$^2$ in Colombia UNDP Project, 2000.

| **Component** | | **Time of use** | **Lifetime production** | **Cost/crop** |
|---|---|---|---|---|
| | **US$** | **Months** | **Crops** | **US$** |
| **Media Bed Grower** | | | | |
| Wood[1] | 2.30 | 24 | 10 | 0.23 |
| Nails | 0.25 | 24 | 10 | 0.02 |
| Hose | 0.09 | 24 | 10 | 0.01 |
| Plastic | 0.91 | 12 | 5 | 0.19 |
| Substrate | 2.87 | 10 | 4 | 0.72 |
| **Total** | **6.42** | | | **1.17** |
| | | | | |
| **Floating bed growers** | | | | |
| Wood | 2.30 | 24 | 11 | 0.21 |
| Nails | 0.23 | 24 | 11 | 0.02 |
| Plastic | 0.91 | 12 | 6 | 0.15 |
| Styrofoam | 2.55 | 12 | 6 | 0.42 |
| **Total** | **5.96** | | | **0.80** |

[1]. Alternative materials such as bamboo can cost less.

3. A Minimum Family Commercial Garden – showing space allocated to bed growers, income generated per $m^2$ per year, garden income with $40m^2$ in production, expected production in kg per crop, per $m^2$ per year and for the entire garden.

| Crop | Beds | Income | Garden Income | Production | | Production | Garden Production |
|---|---|---|---|---|---|---|---|
| | $m^2$ | US$/$m^2$ yr | US$/year | kg/$m^2$ crop | crops/yr | kg/$m^2$ yr | kg/yr |
| Basil | 4 | 35.28 | 141.12 | 6.25 | 9 | 56.25 | 225 |
| Celery | 10 | 28.55 | 285.55 | 9 | 5 | 45 | 450 |
| Green Pepper | 3 | 14.25 | 42.75 | 4.5 | 2.5 | 11.25 | 33.75 |
| Lettuce | 10 | 40.26 | 402.60 | 5.9 | 11 | 64.9 | 649 |
| Cucumber | 2 | 5.28 | 10.56 | 2.2 | 4 | 8.8 | 17.6 |
| Radish | 7 | 33.03 | 231.21 | 3.8 | 10 | 38 | 266 |
| Tomato | 4 | 25.15 | 100.60 | 12.5 | 2.5 | 31.25 | 125 |
| **Total** | **40** | | **1214.38** | | | | **1766.35** |

4. Income and expenses for producing hydroponic vegetables in one $m^2$ in a wood-plastic bed grower. Expressed in US dollars and based on Colombia UNDP project 2000.

| Component | Basil | Celery | Pepper | Lettuce | Cucumber | Radish | Tomato |
|---|---|---|---|---|---|---|---|
| Plants per $m^2$ | 25 | 20 | 10 | 31 | 10 | 255 | 5 |
| Costs for plants | 0.23 | 0.18 | 0.07 | 0.21 | 0.034 | 0.37 | 0.07 |
| Container with substrate | 1.17 | 1.17 | 1.17 | 1.17 | 1.17 | 1.17 | 1.17 |
| Nutrients | 0.4 | 0.9 | 1.49 | 0.26 | 0.87 | 0.26 | 1.49 |
| Water | 0.034 | 0.06 | 0.14 | 0.029 | 0.046 | 0.023 | 0.14 |
| **Total cost per $m^2$** | **1.83** | **2.31** | **2.87** | **1.67** | **2.12** | **1.82** | **2.84** |
| Cost per plant | 0.07 | 0.11 | 0.29 | 0.05 | 0.21 | 0.01 | 0.57 |
| Gross income per plant | 0.23 | 0.4 | 0.86 | 0.17 | 0.34 | 0.029 | 2.58 |
| Net Income per plant | 0.16 | 0.29 | 0.57 | 0.11 | 0.13 | 0.018 | 2.01 |
| Income/$m^2$/crop | 3.92 | 5.71 | 5.7 | 3.66 | 1.32 | 3.3 | 10.06 |
| Crops/year[1] | 9 | 5 | 2.5 | 11 | 4 | 10 | 2.5 |
| **Income/$m^2$/year** | **35.28** | **28.55** | **14.25** | **40.26** | **5.28** | **33.03** | **25.15** |

1. Assumes transplanting from seedlings