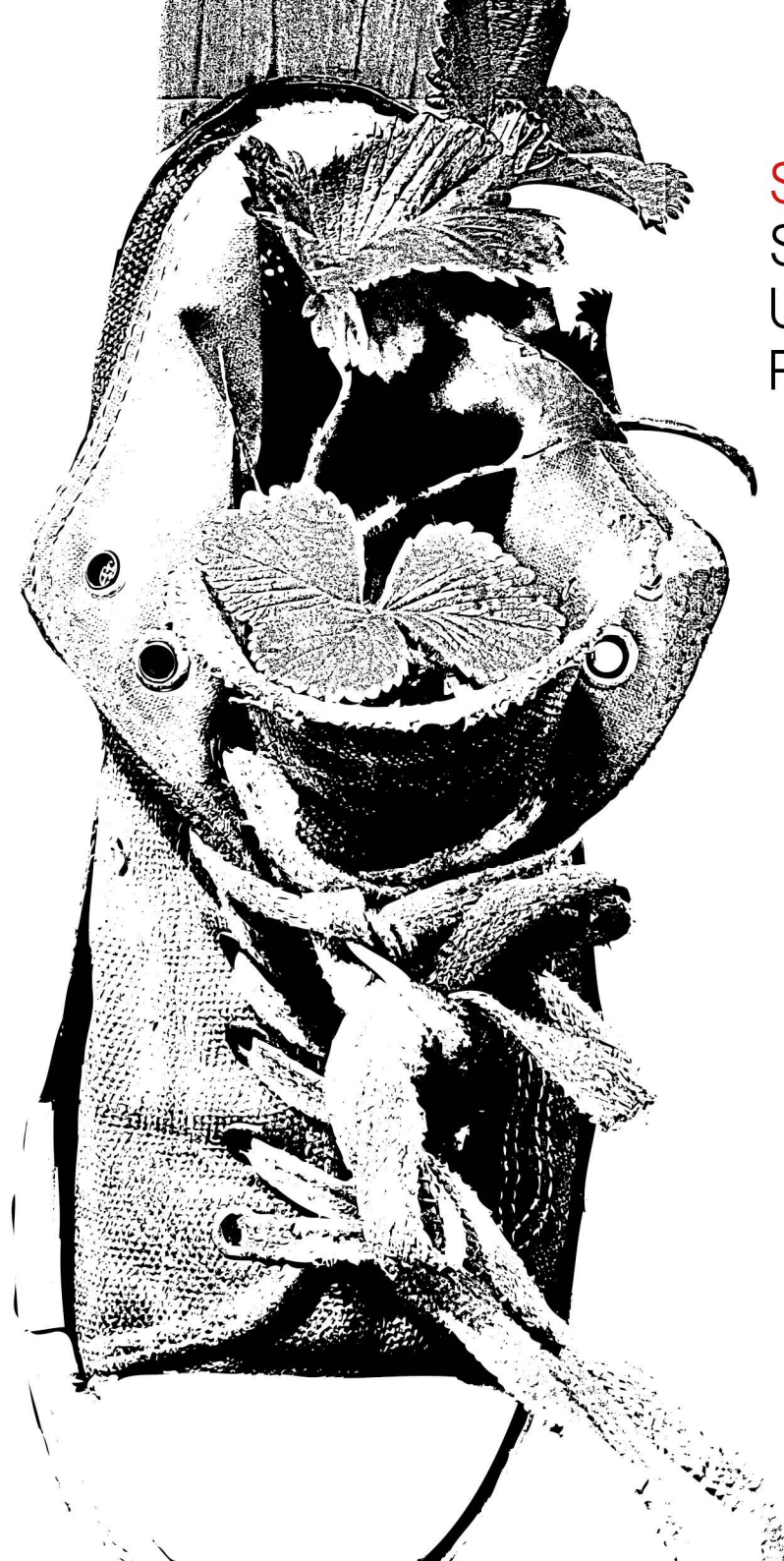


- Manual -

SIMPLIFIED SOILLESS SYSTEMS FOR URBAN VEGETABLE PRODUCTION





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Editors:

*Francesco Orsini*¹

*Nicola Michelin*²

*Giorgio Prosdocimi Gianquinto*¹

Illustrations:

Lucrezia Pascale

Federica Fruhwirth

Book Design:

Lucrezia Pascale & Pietro Nicola Coletta

¹ *Dipartimento di Scienze Agrarie, Università di Bologna - Viale Fanin, 44. 40127 Bologna. Italy*

² *Horticity srl - via Nosadella, 45, 40125 Bologna, Italy*



ResCUE-AB



HORTICITY



Urban gardening activities can encourage lifelong learning among adults by fostering the acquisition of key competences that are fundamental for each individual in a knowledge-based society.

The following educational materials were designed within the context of the European project Hortis – Horticulture in towns for inclusion and socialization (526476-LLP-1-2012-1-IT-GRUNDTVIG-GMP), bringing together the urban gardening experiences from the partner cities, namely Bologna (Italy), Berlin (Germany), Budapest (Hungary) and Cartagena (Spain).

Each partner contributed with its own knowledge on a specific topic in form of an e-book, which successively evolved through an empirical approach of knowledge transfer and participatory review, toward a common and transversal vision of urban agriculture.

The outcome of this participatory process are five knowledgeable e-books covering different topics such as Sustainable Community Gardening in Cities (e-book 1), Sustainable Urban Garden Management (e-book 2), Urban Garden Cultivation Systems (e-book 3), Simplified Soilless Systems for Urban Vegetable Production (e-book 4) and Eating closer to home: An urban consumer's manual (e-book 5).

We hope these material will bring a new dimension to your work and inspire you in turning your life and city greener.



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1. FOREWORDS



/ First documented experiences of soilless cultivation date back about three hundred years ago. However, plant cultivation outside the soil was a common practice already in ancient cultures, as shown by the Babylonian hanging gardens, the floating islands of lake Titicaca in the Andes, or the Burmese Inle Lake in South-East Asia. During the twentieth century the technology associated to soilless cultivation has been growing dramatically, putting the basis for the diffusion of High Technology Soilless Culture (HTSC) in intensive farming systems for the great advantages offered to growers. HTSC systems are nowadays characterized by a high level of automatism with accurate climatic control in the growing environment (usually greenhouses), adjustment in the plant input (water and nutrients) in response to the plant growing stage, and a great mechanization of the growing process. The main advantages of soilless cultivation are the independence from fertile soils, the reduced water requirements and the high production efficiency, none of them necessarily correlated with the technological level of the system. Indeed, simplified soilless cultures (SSC, also referred to as Simplified Hydroponics, SH), present several other benefits, such as being easy to build and manage, require little labor, present lower incidence of soil-borne diseases, make use of low-cost/ recycled materials to build growing containers, enable to obtain higher yield and intensify productivity and shorten the chain between harvest and consumption, with reduced product depletion. Consistently, SSC are spreading in urban areas to find solutions to low fertility of the soils, low irrigation water availability, small extension of cultivated lands and environmental pollution. Successful experiences of SSC have been conducted in the last decades all over the world and nowadays a relevant number of growing solutions is available, adapting to the peculiar social and environmental conditions of the most diverse contexts. However, it is

necessary to keep in mind that soilless systems have specific requirements. As the ecological system is rather small, an autonomous circular flow of regeneration and requalification is not provided. Moreover, although soilless systems offer the opportunity to be quite mobile, this bears a risk: people live in a neighborhood and cannot move as easy as an elevated bed could be moved elsewhere. Nonetheless, SSC may represent the only gardening opportunity in many urban contexts. This e-book will guide you in creating your garden, regardless to the place you are and the soil you have.

2. CHOOSING THE SYSTEM



2.1 / SOILLESS SYSTEM PRINCIPLES

Choosing the most suitable growing system shall take into consideration the space where it will be built, the available infrastructures (walls, fences, etc.), the materials to be used, the investment to be dedicated and, not ultimately, the main purpose of gardening (productive, aesthetic, relaxing, etc.). Some of the systems hereby described will serve more efficiently for community cultivation, while others will be more adapted to home or individual use. As a general rule, when initiating community soilless gardening, it is a good habit to comparatively test some different garden typologies in order to identify those that may better adapt to the climate, possibly also assessing the applicability of innovative solutions made out of available material.

Simplified soilless systems may be divided into two main categories, according to the destiny of the water drained after irrigation: closed loop system are those that recycle drained water and re-use it for further irrigation, open loop cycle are those where exceeding water is drained and discarded. While the former present greater water use efficiency (enabling to save up to 80% of the water commonly used in on-soil cultivation), the latter are generally cheaper and require lower technology and skills for the management of plant nutrition.

Another classification may be operated considering how the water (or nutrient solution) is provided to the system. Some systems (e.g. floating systems, deep water culture) maintain the water reserve always in contact with the plant root system, whereas other systems (the great majority of those presented in the manual) have water provided periodically and then left to drain. Once again, the former require lower technology and work and the latter have lower problems

due to the greater oxygenation of the water reserve, giving generally more productive results. In the present manual some of the most commonly used micro-garden systems will be described. However, it is important to state that there is not a best cultivation system, but indeed, there can be an optimal solution according to every situation. The hereby illustrated growing systems are those that have shown satisfactory results when applied in a range of experiments in urban contexts. The systems shown below are:

- vertical Bottles System;
- modified NFT System;
- box Systems;
- floating Systems;
- hortilla;
- growing baskets and pots;
- bag Cultivation Systems.

2.2 / VERTICAL BOTTLES SYSTEM

The Bottles system was first used in Brazil and successively adopted in several projects for the promotion of SSC in other Latin American countries (e.g. Peru), as well as in Western Africa (e.g. Burkina Faso, Ivory Coast, Mauritania), and South-East Asia (e.g. Myanmar). Recently, a variant made out with bamboos has been successfully introduced and tested in Myanmar and Ivory Coast.

In Europe it has been successfully adopted in Bologna (Italy) with simplified soilless garden in schools and on the rooftop of public housing buildings (Fig. 1). Being a closed system it allows to maximize water and nutrient use efficiency, with complete re-use of the exceeding nutrient solution. Moreover, it permits the recycling of discarded material like plastic bottles.

Main elements of a bottle system are:

- ***plant containers***: plants are hosted in waterproof containers, i.e. plastic bottles. The bottle is generally used upside-down. On the

bottom of the container (bottle lid) a hole is operated and the drainage pipe is inserted. Containers are filled with a growing substrate (see specific section), possibly constituted by a thin layer (3-4 cm) of highly draining substrate (e.g. clay pebbles, perlite) on the bottom, and then filled with a water retaining substrate (e.g. coir) or with a mixture (e.g. coir + perlite + clay pebbles). It is advisable to add a filter (e.g. water permeable textile) on the lid in order to avoid small substrate particles to log the draining pipe.



Figure 1. Examples of vertical bottle systems.

- ***hydraulic system***: two main elements are present, namely the irrigation and the drainage systems. Other than allowing water recycling, the closed-cycle reduces water loss from evaporation. Moreover, it limits the infiltration-related dilution of the nutrient solution during rains. The irrigation system is composed by a water submerged pump connected to a timer that will provide the nutrient solution to the plant containers through a delivery system composed

by polyethylene (PE) pipes (\varnothing 16 mm) pipes and micro-pipes (\varnothing 3 mm). Drippers ($2-5 \text{ l h}^{-1}$) are used for regulating water flux.

The adoption of variable drippers may enable easy opening and cleaning by the operator. Drippers may be cleaned and sterilized by 24-48 hours submersion in a solution containing vinegar, citric acid or bleach. The length of the irrigation system (pipe + micropipes) shall be calibrated at the garden size and the distance of the plant containers from the main pipe. Micro-pipe length should be however uniformed in order to avoid differences in water pressure and distribution across the garden.

The drainage system is responsible of bringing the exceeding water back to the main container, in order to be re-used afterward. It may be composed of micro-pipes (\varnothing 7 mm, whose greater diameter should enable to avoid logging) that are inserted directly on the lower end of the plant container (e.g. bottle lids). Those micro-pipes are then directed onto main drainage pipes (\varnothing 20-25 mm) and finally to the re-collection tank.

- **support system**: a vertical support system will hold the plant containers and the irrigation system allowing to drain (by gravity flow) excessive water back to the collection tank. As a general rule, the main irrigation pipe should be placed about 10 cm above the plant containers. The support system may be self-sustaining or connected to a wall. An efficient solution is provided by the adoption of protection fences that will also offer support for bigger plants (e.g. tomato, cucumber, bean, etc.). The basic structure of the system is shown in Fig. 2.

How the Vertical Bottle System works

Daily operation and maintenance of the system includes to check and clean all the drippers once a week, to perform weeding in and around the system when needed and to monitor the possible presence of pests and diseases. Once per year, usually when the system goes



Figure 2. Basic structure of vertical bottle systems.

under maintenance, the substrate shall be removed and replaced or disinfected. At the same time, the hydraulic system should be washed with a solution made of 0.005 liter of household bleach dissolved in 1 liter of water. Afterwards, all the system should be rinsed well with plain water.

2.3 / MODIFIED NFT SYSTEM

The NFT (Nutrient Film Technique) system was first developed by Dr. Allen Cooper in 1965 in England, consisting in ditches with a slope of 1% in which the nutrient solution was circulating.

This original design was modified by the Centro de Investigación de Hidroponía y Nutrición Mineral (CIHNM) of the Universidad Nacional Agraria La Molina (UNALM) in Lima, Perú, to make feasible the production of different vegetables and to adapt the technique to the reality of Latin American countries (Rodríguez-Delfín, 2012). A modified NFT system was successfully adopted in rooftop soilless gardens in Bologna (Italy) (Fig. 3) and Lima (Peru) (Fig. 4).

This modified NFT system uses as culture channels water and/or drainage PVC pipes in which the recirculation of the nutrient solution is intermittent (for periods of 15 minutes every half hour) and regulated by a pump located into a tank. In the culture channels, 25 mm of nutrient solution are maintained while the pump is off, enough level

so that the roots are in permanent contact with the nutrient solution (Rodríguez-Delfín et al., 2004 as cited in Rodríguez-Delfín, 2012). The system implemented in Bologna is similar to the one designed by the CIHNM, with slight modifications: the PVC pipe has a drip irrigation system on it and also a 1% slope so the water can go back to the tank and be reused.



Figure 3. The modified NFT system in Bologna, Italy. Figure 4. The modified NFT system in Monterrey, Lima, Perú.

How to assemble a modified NFT System

Materials needed: 4 inches diameter PVC pipes (meters necessary according to the space available), PVC glue, net pots, cable ties, drill with a saw cup (same measure as net pots diameters), tank (more or less 500 l capacity), black poly pipe (Ø 16 mm), smaller poly tube (Ø 3 mm), drippers, connections.

Assembly instructions: First of all, the PVC pipes are fixed on the vertical structure (fences, walls). To do that, the different pipes (generally 1 to 3 m long) are fit and stuck together, using pipe fittings

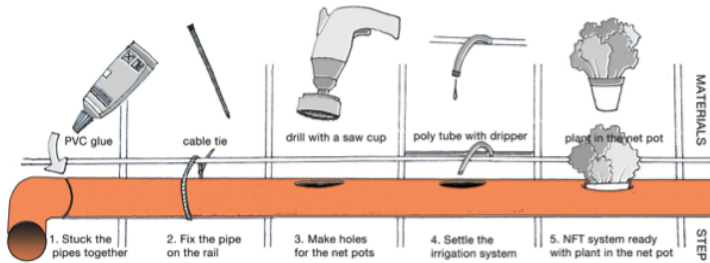


Figure 3. Rosa Rose Garden, Berlin in between old residential buildings, summer 2013.

2.4 / BOX SYSTEM

The box system is substantially a cultivation table, where plants are grown into a box structure (Fig. 6). Selecting the proper box type and size is crucial, and it shall consider different factors: available space, technical and economic means, needs and aspirations of the family or group involved in the activities. Box systems are generally made out of raw wood or recycled pallets. Past experiences suggest a size of about 1 m² (1.2 x 1 m) with borders at least 20 cm high. In warmer climates, boxes shall be elevated by means of 4 or more supports to allow a good air circulation underneath and to avoid excessive heating exchange from the soil.

In this way root overheating and poor oxygenation of the water are avoided.

The system has been successfully used in a wide range of climates (Fig. 7) and resulted to be more suitable for medium-bigger sized vegetables such as tomato, pepper, cucumber, eggplant and chili pepper, which need more space for root development. Indeed it is also good for carrots or leafy vegetables (lettuce, spinach, etc.).

It shall be considered that, as compared to other systems, the box system presents lower water use efficiency due to the higher evaporative surface of the exposed substrate.

However, water saving as compared to traditional on-soil agriculture is still greatly appreciable.



Figure 6. Basic structure of a box system. Figure 7. Examples of box systems in Bologna (Italy, top), Teresina (Brazil, second row), Trujillo and Lima (Peru, third row), Abidjan (Ivory Coast, bottom left) and Tidjika (Mauritania, bottom, right).

How to assemble a Box System wooden container

Materials needed: 2 pallets (preferably of the same size and with 15 cm high boards), 4 iron angles, 16 screw more or less 3 cm long, 4 screw more or less 8 cm long, wood impregnating agent, black polyethylene water-proof sheet.

Instructions: Disassemble one pallet paying attention not to break the wooden boards. Smooth the wood surface of all the boards and the

other pallet (Fig. 8). Once everything has been rubbed down, go on with the assembly setting up on the pallet 8 boards (2 per each side), which are going to constitute the edges of the container.

These edges should assure a depth of around 30 cm, necessary for the roots growth. To set up the boards, start on the shorter sides fixing the first board directly on the pallet with two screws.

All the other boards are fixed one with another with the 4 angle irons (one per each angle). Once the wooden container has been assembled, it is good to use a wood impregnating agent to make the wood waterproof and resistant.

Afterwards, the internal part of the container is sealed with waterproof sheets. For this purpose, the soil bags or rubbish bags can be used, considering that it is important to leave some openings to allow a good drainage.

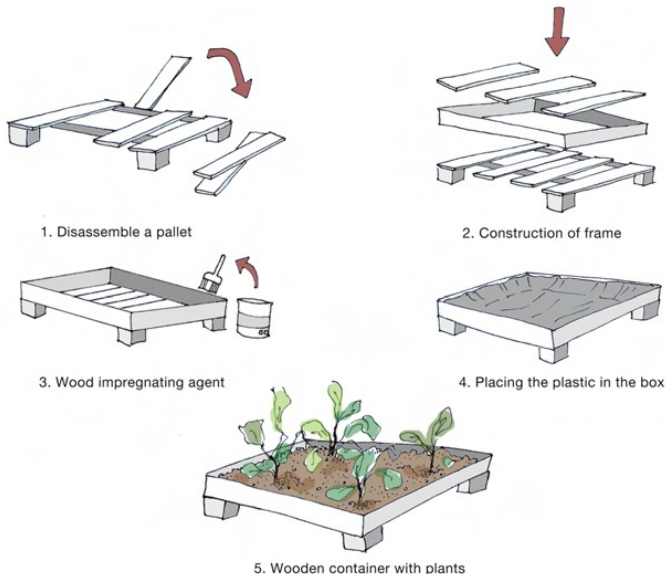


Figure 8 Step-by-step procedure for building a box system.



Figure 9. Simplified soilless box systems on the rooftop of a public housing building in Bologna, Italy.

How to assemble a Box System wooden container

As previously mentioned, the box system is composed by a wooden container made waterproof with plastic film and filled up with the growing substrate. Plants are either transplanted or sown directly onto the system and watered with NS one to three times per day (about 20 l per day per m²). If a closed loop cycle is adopted, the base of the system shall be slightly declined and the exceeding solution flows to a tank placed below through a drainage pipe to be recycled.

2.5 / FLOATING SYSTEM

The general characteristic of a floating system is that plants are fixed on polystyrene beds that float over a tank (Fig. 10). In particular, in the hereby presented case, plants are located into net pots (filled with a growing substrate as mechanical support) placed on holes made in polystyrene boards. These boards float on the nutrient solution surface, in which the roots of the plants are dipped constantly.

In this way the water surface is completely covered by the floating bed, which allows a very limited growth of algae, and at the same time the nutritive solution is oxygenated by a pump to allow better conditions in the liquid medium. In general, the floating system does not allow to grow a big range of vegetables and it is commonly used for growing leafy vegetables like lettuce, leaf beet and celery, or aromatic herbs such as basil, coriander and parsley (Fig. 11). As for the box system, the identification of the proper container size shall consider several factors: available space, technical and economic means, and the aspirations of the family or group involved in the activities. Furthermore, the size of the container shall take into consideration the exact measures of the panel that will support the plants. For simplification, the following instructions are based upon the availability of polystyrene panels (5 to 7 cm thick) with specific measure of 1.20 x 0.80 m that correspond to standard pallet size as well as standard floating panel measures. When other measures are found, the wooden box shall be re-sized accordingly.



Figure 11. Simplified soilless box systems on the rooftop of a public housing building in Bologna, Italy.

How to assemble a wooden tank for the floating system

Materials needed: 2 pallets (preferably of the same size and with 15 cm long boards), 4 iron angles, 16 screw more or less 3 cm long, 4 screw more or less 8 cm long, wood impregnating agent, black polyethylene water-proof sheet, polystyrene boards, drill with a saw cup.

Assembly instructions: Disassemble one pallet paying attention not to break the wood boards. Smooth the wood surface of all the boards and the other pallet (Fig. 12). Afterward, go on with the assembly setting up on the pallet 8 boards (2 per each side), which are going to constitute the edges of the container. These edges should assure a depth of at least 20 cm to ensure an adequate NS content. To set up the boards start on the shorter sides fixing the first board directly on the pallet with two screws. All the other boards are fixed one with another with the 4 angle irons (one per each angle). Once the wooden container has been assembled, it is good to use a wood impregnating agent to make the wood waterproof and resistant. Afterwards, the waterproofing with plastic material should be done and in this case there should be no openings or leakages to make it efficient. To do that, a black thick plastic is required; its function is to avoid dampening and rotting of the wood and the quick loss of nutrients, and the black color is to avoid the formation of algae.

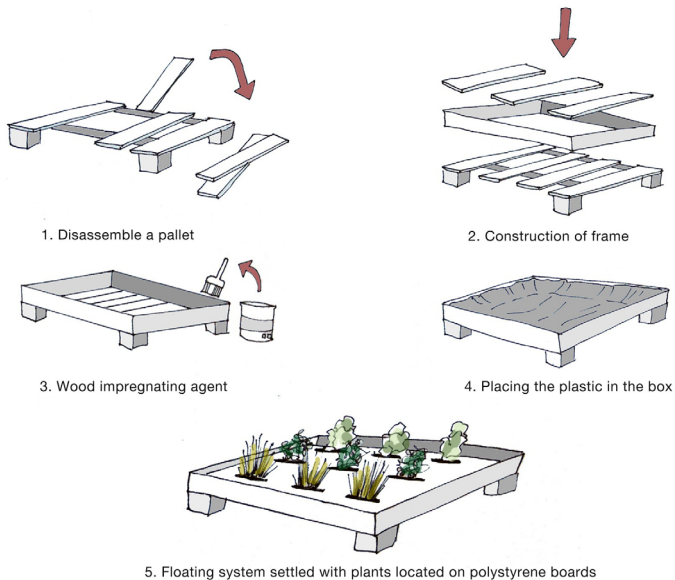


Figure 12. Step-by-step procedure for building a floating system.

Once the container is ready, the polystyrene boards have to be prepared and holes to put the net pots should be made using a drill with a saw cup, providing a distance of around 20 cm between them.



Figure 10. Basic structure of a floating system.

How the floating system works

Plants are sown directly or transplanted onto the system. Roots will exit from the bottom of the polystyrene panel and absorb water and nutrients from the nutrient solution beneath.

Until sufficient root development, seedlings shall be manually watered or panels may be gently pressed down in order to increase the

substrate moisture. To guarantee a good functioning of the floating system, it is important to oxygenate constantly the nutrient solution below the polystyrene boards. As a matter of fact, the basic concept of hydroponics is that roots suspended in moving water absorb food and oxygen rapidly and consequently of special concern is the availability of oxygen. The grower's task is to balance the combination of water, nutrients and oxygen with the plant needs in order to maximize yield and quality. The oxygenation can be achieved using an aquarium air pump that contributes to the oxygen diffusion in the floating container. Otherwise, oxygenation may be achieved by vigorously moving the water by hand or with a piece of wood two to five times per day, paying attention not to break the plastic film. In warmest season/location, the low oxygenation may become a problem and the system may not provide satisfactory results.

2.6 / HORTILLA

Growing bottles (Hortilla) are the smallest simplified soilless system made of recycled plastic bottles. Every single bottle constitutes a growing unit, and the size of the garden may be easily adapted upon bottles and space availability. The system is composed of two parts: the lower one is the nutrient solution reservoir and the upper hosts the plant root system (Fig. 13).

How to build a growing bottle

Place one bottle vertically and cut it in two parts at about half of its height (Fig. 13). Reverse the neck of the bottle and place it upside down into the bottom of the bottle. Fill the upper part with substrate and sow your essences. Leave the cap closed tight and water the substrate until it looks uniformly wet. Place the growing bottle in a cool shaded place until germination and then move the bottle under the direct sun. Make few small holes in the cap with a nail and fill the lower reservoir with nutrient solution. The system is adapted for



Figure 13. Step-by-step procedure for building growing bottles.

growing small leafy vegetables (e.g. lettuce) or aromatic plants (e.g. coriander, parsley, basil) (Fig. 14).

How the growing bottle works

The water in the reservoir moisturizes the substrate and allows plant germination and growth. In warmest periods/locations it is important to open frequently the bottle by separating the two parts in order to oxygenate the nutrient solution.



Figure 14. Hortilla a Abidjan, Costa D'Avorio.

2.7 / GROWING BASKETS AND POTS

Growing baskets (Fig. 15) and pots are one of the simplest way to grow plants on SSC systems. The growing container is made out of recycled containers (e.g. baskets, cans, etc.) and has a drainage hole in its lower part for the exceeding water/nutrient solution. These systems usually operate with open cycle, and therein have a lower water- and nutrient- use efficiency. For this reason, the nutrient solution is only periodically applied, and the irrigation should be provided in several small applications in order to avoid water logging and losses. An organic substrate (e.g. compost) may be used in order to provide a reserve of minerals. In this case, growth rate may be slower, but at least the use of soluble fertilizers can be avoided (Fig. 16).



Figure 15. Growing Baskets.



Figure 16. Vegetable garden in pots with drip irrigation system, or in hand watered pots. Examples in Bologna, Italy and Abidjan, Ivory Coast.

2.8 / BAG CULTIVATION SYSTEMS

The simplest way of growing vegetables out of the soil is to fill bags with substrate and to use them to host plants (Fig. 17). In this system no closed-cycle can be used (the exceeding water is lost), but through the use of an organic nutrient media (e.g. compost), it may be possible to avoid the use of mineral fertilizers (Fig. 18). Possible improvements of the system may be related to the adoption of a drip irrigation system that provides timely and less consuming irrigation (Fig. 18). In this case, a plastic film could be placed underneath the bags to drain the exceeding NS on a recollection tank for re-use.

Successful examples of bag cultivation systems are present in very different climatic and social environments: they are commonly used for growing vegetables in the Prinzessinengarten (Fig. 18) in Berlin, as well as in the so called “Vertical Farms” of Kibera, Nairobi, Kenya. In the Kenyan capital, these systems saved the slum population from starving during the food crisis of 2007-2008, allowing leafy vegetables such as spinach or beet to be easily grown.



Figure 17. Bag cultivation system.



Figure 18. Bag cultivation systems in the Prinzessinengarten, Berlin and in Abidjan, Ivory Coast.

WHERE TO BUILD THE GARDEN



3.1 / SITE SELECTION AND ENVIRONMENTAL ADJUSTMENTS

The independence from fertile soil may be claimed as the main advantage of simplified soilless cultivation in cities. Soilless gardens may be placed in balconies, terraces, rooftops, paved courtyard, etc. As a general rule, main elements to be considered when choosing an area to build a simplified soilless garden may be listed as follow:

- set the micro-garden in areas that receive at least 6 hours of direct sunlight per day. It is advisable to use a space with good illumination, orienting the micro-garden longer side to the North. Avoid shaded zones, areas near houses or other buildings, as well as areas exposed to strong winds;
- choose an area with adequate and easy-to-access water supply to facilitate irrigation;
- fence the micro-garden to limit bird attacks and avoid domestic animal access (dogs, cats, etc...). This will also deter the entry of irresponsible people and acts of vandalism; however, in order to reduce the threat of vandalism it is extremely important to promote social responsibility, e.g. a neighbourhood identifying with the garden and thus taking care;
- keep the areas around the micro-garden free from weeds, which can host diseases and insects that may damage the vegetables.

In cities, the heat island effect results in increased temperatures as compared to rural areas. Consistently, temperatures experienced during warmest periods may be excessive to enable plant growth. The adoption of shading structures has proven to provide great benefits to the micro-garden productivity. Nevertheless, especially when gardens are placed on rooftops or in wind exposed environment, it is

extremely important to create shading structures that are well fixed and resilient to wind (Fig. 19).



Figure 19. Shading structure in a public housing building rooftop garden, Bologna Italy.

CULTIVATION TECHNIQUES



4.1 / PLANT NUTRITION

In order to grow and provide yield, plants need nutrients. In soilless cultivation systems, mineral elements are dissolved in a nutrient solution in proper quantity and proportion. The essential nutrients required for plant growth are 13, classified as macronutrients (needed in greater amount), e.g. Nitrogen (N) Phosphorus (P), Potassium (K), Calcium (Ca), Magnesium (Mg), Sulfur (S) and micronutrients (those that the plant needs in lower quantity), eg. Iron (Fe), Manganese (Mn), Boron (B), Copper (Cu), Zinc (Zn), Molybdenum (Mo) and Chlorine (Cl). Carbon (C) and Oxygen (O) are supplied by the atmosphere, while Hydrogen (H) is supplied by water. Each element is utilized in different proportions and has specific functions for the plant development.

Below, the main functions of each element are listed.

- **Nitrogen** (*N*). It is the element that plants require in higher quantity. Being a main component of chlorophyll, it is responsible of plant greenness. It promotes rapid growth, stimulates vegetative production and improves vegetable and fruit quality raising proteins content. N deficiency symptoms are identified by light green-yellow leaves and a slow and limited development. Extreme pH contributes to N deficiency.
- **Phosphorus** (*P*). It stimulates root and flowers formation and development, contribute to seeds maturation, promotes fruit color and helps seed formation and plant vegetative vigor. Deficiency is associated with purple leaves, branches and trunk, rachitic aspect, low fruit number and scarce seed production.

- **Potassium** (*K*). It provides vigor and resistance against diseases, raises seed size, improves fruit quality. It is also very important for stomatal control. K deficiency appears as leaf burning.
- **Calcium** (*Ca*). It stimulates lateral roots formation and development, improves the general plant vigor, and stimulates seed production. The deficiency appears with leaf margin burning and blossom end rot in tomato and pepper fruits.
- **Magnesium** (*Mg*). It is the main component of the chlorophyll, necessary for sugar biosynthesis. The deficiency appears with light greenness of the young leaves and excessive roots ramification.
- **Sulphur** (*S*). It preserves an intensive green color, stimulates seed production and helps vigorous plant development. Deficiency produces short shafts, weak, yellow color and slow and rachitic development.
- **Copper** (*Cu*). It is for 70% concentrated in the chlorophyll.
- **Boron** (*B*). It helps fruit and vegetable formation and quality. It is important for good legume seeds. Excess is extremely dangerous and may lead to plant death.
- **Iron** (*Fe*). Required in chlorophyll biosynthesis, N fixation and respiration.
- **Manganese** (*Mn*). It speeds up germination and maturation, improves calcium, phosphorus, and magnesium uptake. It has photosynthetic functions.
- **Zinc** (*Zn*). It is necessary for chlorophyll formation and for plant growth. It is an important enzyme activator. Plants deficient in Zinc have low protein content.
- **Molybdenum** (*Mo*). It is fundamental for nitrogen fixation in legumes and for vitamin biosynthesis.
- **Chloride** (*Cl*). It is usually present in the water. Excess may lead to salinity symptoms.

4.2 / NUTRIENT SOLUTION (NS)

The nutrient solution is constituted by water and dissolved minerals salts. Main features of the nutrient solution are pH and Electrical Conductivity (EC). pH ranges from 0 to 14, with lower values being the most acidic and higher values being the most alkaline. Extreme values are incompatible with plant's life, and the nutrient solution may be defined based on its pH as strongly acid (pH < 5.5), acid (pH 5.5-6.0), sub-acid (pH 6.0-6.8), neutral (pH 6.8-7.3), sub-alkaline (pH 7.3-8.0), alkaline (pH 8.0-8.5), strongly alkaline (pH > 8.5). Optimal pH values in the nutrient solution are found between pH 5.5 and 6.5.

Between these values all salts are kept in solution and are available for the plant. Above 6.5, some elements (e.g. P, Mn and Fe) precipitate and become unavailable for the plant. Similarly, precipitation of Mg and Ca occur when the pH falls below 5.5. pH is measured using a pH-meter. EC is a measure of the ability of a certain liquid solution to conduct electricity. Being related to the concentration of the dissolved salts, it provides an indication of the salinity of the nutrient solution. It may be expressed in dS m^{-1} or mS cm^{-1} or $\mu\text{S cm}^{-1}$ ($1 \text{ dS m}^{-1} = 1 \text{ mS cm}^{-1} = 1000 \mu\text{S cm}^{-1}$). A good nutrient solution in moderately warm climates should present an EC ranging 1.5 to 2.2 dS m^{-1} (1.5-2.2 mS cm^{-1} or 1500-2200 $\mu\text{S cm}^{-1}$). Indeed, due to the low water quality and the differences in fertilizer availability, suitable nutrient solution may be prepared up to 2.5 dS m^{-1} (2.5 mS cm^{-1} or 2500 $\mu\text{S cm}^{-1}$).

EC is measured using an EC-meter. It is extremely important to prepare the nutrient solution properly, uniformly dissolving the mineral salts in the water.

For the correct preparation of a standard nutrient solution an easy-to-use software based on the MS-Excel platform (FRESH – Fertilizers Reckoning for Simplified Hydroponics) is provided altogether with this manual (Fig. 20).

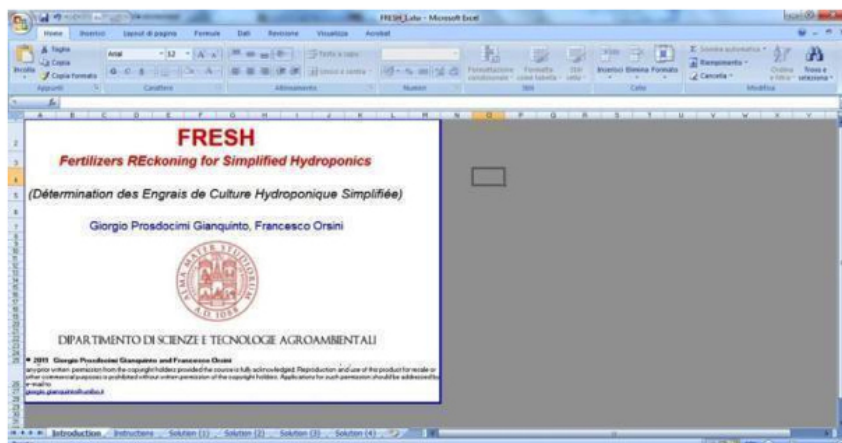


Figure 20. Interface of FRESH.

Step-by-step procedure for NS determination with FRESH.

The interface is organized in three sections. Sheet 1 is the “Introduction” page, with the credits of the software. Sheet 2 contains the “Instructions” for the use of the software. Other sheets (named “Solution”) include the calculation of the nutrient solution starting from the available fertilizers. In the solution sheets, cells present different colors: green cells are those that can be modified by users, according to the fertilizers that may be found in the selected location, their price and the reservoir capacity. Red cells include the calculation provided by the software and are not modifiable by the user. Purple cells represent the threshold to be respected in the preparation of the nutrient solution. To use the software, the procedure to follow is reported in Table 1.

Some suggestions.

- The amount of the fertilizer with microelements (Fe, Cu, Zn, Mn, Mo) usually ranges from 50 to 250 grams per 1000 liters of NS. Start to define the nutrient solution from this fertilizer, with an amount of

/ Table 1. STEP-BY-STEP PROCEDURE FOR DETERMINING NS WITH FRESH.

STEP	Cell/s	Action
1	A2	Indicate the location (optional).
2	A5	Indicate the reservoir capacity (in liters).
3	B7 – K7	Indicate the names of the available fertilizers.
4	B9/B23 K9/K23	For each fertilizer, enter the concentration (%) for each mineral element as stated in the fertilizer label. For example in B9 include the N% of first fertilizer, in B10 the P ₂ O ₅ % of the first fertilizer and so on.
5	B25-K25 M9-M23 N9-N23 O9-O23	Enter the quantity of fertilizer (in grams) that you plan to dissolve in 1000 liters of water, and verify that the concentration of each element (M9-M23) falls within the range identified by the columns min-max (N9-N23 and O9-O23).
6	M9-M23 B25-K25	If the concentration of certain elements (M9-M23) falls far outside the threshold min-max (N9-N23 and O9-O23), it is required to adjust the quantity of the fertilizers (B25-K25) and re-check.
7	B26-K26	If the concentration of certain elements (M9-M23) falls far outside the threshold min-max (N9-N23 and O9-O23), it is required to adjust the quantity of the fertilizers (B25-K25) and re-check.
8	B27-K27	Enter in line 27 the cost per kg of each fertilizer (optional).
9	B28-K28	In line 28 the cost of each fertilizer in the reservoir is indicated.
10	B29	In cell B29 the total cost of fertilizers per each reservoir is indicated.

100-200 g.

- The amount of fertilizer with macro-elements (N, P₂O₅, K₂O, S, MgO, CaO), usually ranges from 250 to 1000 grams per 1000 liters of NS. Start including 500 to 750 grams.
- While adding fertilizers, check that the total fertilizer concentration in the NS (cell O27) ranges from 1 to 3 grams per liter (as reported in cells O28 and O29). This should result in a proper EC value (cell M25).
- In a warm and dry location or season, it is advisable to reduce the strength of the nutrient solution by limiting the EC value to 1.4-1.8 dS m⁻¹. In cool and rainy climates, instead the EC of the NS may be enhanced up to 2.5 dS m⁻¹. If during the determination of the NS the EC values cannot fall within these thresholds, it is advisable to carefully check the plant response. If salt stress symptoms (yellowing and burning of the leaf margins) occur, follow this procedure:
 - a. reduce the amount of each fertilizer in measure of 20-30% (excluding the fertilizer with micro-elements);
 - b. reduce intervals between irrigations and shorten irrigation time;
 - c. once every ten days perform an irrigation with water only.

Tips for preparing/storing the NS

- Dissolve salt minerals completely into the water. In order to do so, dissolve each fertilizer in a bucket with some water by mixing until all solid residues disappear, and then add it to the reservoir already filled with water. Avoid contact between fertilizers, in particular avoid contact between fertilizers containing sulfate and phosphate with those containing calcium.
- Store solid or liquid fertilizer in a dark cool place. Always label fertilizers.
- When preparing a new solution, measure accurately each component, in order to avoid misbalanced NS or nutrient precipitation. Use common water at room temperature.

4.3 / SUBSTRATE

The substrate main function is to support the plants, while allowing a uniform flow of the nutrient solution. The substrate does not provide a nutritional function and should be inert in this regard. Suitable substrates can be constituted by different materials like, for instance, small stones, sand, pumice, vermiculite, carbonized or fermented rice hulls, coconut fiber, cocoa and peanut shavings, and combinations of the above.

A good substrate shall present the following characteristics:

- resistant to degradation (durability);
- not containing soluble mineral substances;
- not containing any macro and micro organisms (to limit disease risks);
- dark, in order to allow root growth and reduce algae formation;
- good water retention, but at the same time drain easily;
- maintain high surface moisture;
- easily available in local context;
- affordable, light and easily transportable.

In the present chapter the properties of some of the most commonly used substrates in simplified soilless cultivation are described.

• ***Potting soil.*** Is a medium that can be used to grow herbs and vegetables in a pot or other durable container. It is also called potting mix or potting compost. It generally contains peat, composted bark, sand, perlite and recycled mushroom compost, at variable concentrations. Despite its name, very little or none soil is used in its preparation since it would be too heavy for growing plants in pots (low porosity). Its applicability in simplified soilless systems may be improved by mixtures with other substrates (e.g. expanded clay, perlite).

• ***Expanded clay aggregate.*** (clay pebbles)

Clay pebbles are a lightweight ceramic shell with honeycomb core produced by firing natural clay to temperatures of 1100 - 1200 °C. After cultivation, clay pebbles may be cleaned and sterilized by

washing them in a solution of white vinegar, chlorine bleach, or hydrogen peroxide, and rinsing completely. The low weight and high porosity make clay pebbles a valuable options in rooftop gardening.

- **Perlite**. Perlite is an amorphous volcanic glass that after treatment at 850-900°C loses water resulting in expansion of the material to 7–16 times its original volume. In horticulture, perlite can be used as a soil amendment or alone as a medium for hydroponics or for starting cuttings. It is characterized by high permeability/low water retention, therein helping excessive water drainage. It may be used alone when frequent irrigations are supplied, or it should be mixed with water retaining substrates when drought may occur. Due to the low weight, perlite may be easily used on rooftop agriculture.

- **Coir** (*Coconut fiber*). Coconut fiber is a substrate deriving from the shell of coconut after grinding, pressing and selecting it. By grinding, the substrate is reduced into small pieces that can easily host plant growth. By pressing, the substrate volume is reduced, and by selecting the biggest not grinded pieces are eliminated. The physical characteristics of the processed substrate are optimal for soilless cultivation and coconut fiber is amongst the most used substrates also in commercial hydroponics. A common problem that may be experienced when using low quality coconut fiber in soilless cultivation is due to salinity. Coconut palms are usually cultivated along coastal areas and the salt spray from the sea winds may cause salt deposition on coconuts. The problem may be easily overtaken by washing the substrate. The substrate is submerged in water for two to three days. The washing process may allow to reduce the substrate salinity from initial values of 3.0 dS m⁻¹ down to 0.3 dS m⁻¹.

Soil preparation in specific gardening conditions: challenge elevated plant beds

An important aim of urban community gardening is environmental and climate protection. Often, this is addressed by biological cultivation methods, composting and soil preparation. A practical example may be

given by the experiences in the Allmende-Kontor community garden in Berlin. Due to the disadvantage of having to plant in elevated beds, the possibility to create a sustainable soil preparation is very limited. Weather conditions such as a strong exposure to wind and sun dries up the soil in elevated beds quickly and plant nutrients get lost fairly quickly. Additionally, high beds such as bakery cases or milk cartons do not store water very well, thus needing a lot of watering, which is not the most sustainable method of gardening.

In this specific situation, elevated beds need special care in ways of sustainable watering, mulching and soil composting in order to prevent from drying out and losing soil quality quickly. Thus, an active gardener with a professional background in ecology initiated a group of gardeners in soil preparation questions. In several workshops, she introduced a quick-composting method, which allows producing organic soil within weeks only.

A quick description of the composting activities is hereby provided by the Community Compost Team in Allmende-Kontor: “We compost the garden waste conjointly according to a biological-dynamic quick procedure. From the collected garden and kitchen waste there will be fresh and high-quality soil for our high beds after at most three months. You are welcome to visit our container to collect garden waste and our “turtle”: underneath the tortoiseshell the material decomposes. The model shows the results after one month and after three months, respectively.” On a regular basis, the Community Compost Team organizes training workshops on composting.



Figure 21. Process of quick composting in Allmende- Figure 22. Visualized process of composting in 3 steps: (1) garden waste is collected by around 800 gardeners and then sticks are cut down into small pieces and piled up into different layers: green garden waste – brown garden waste – organic kitchen waste. For the compost to breathe a hole in the middle provides air. Organic essences speed up the process of composting, and high quality soil is ready within in 3 months. Underneath the compost turtle temperature reach 60° C.

NURSERY AND SEEDLING DEVELOPMENT



Plants may be directly sown in the soilless system or may be transplanted once they have developed few true leaves. It is generally preferred to transplant the new plant soon after the previous harvest, since in this way the time interval between harvests can be reduced. Usually leafy vegetables (e.g. lettuce, spinach) and medium-sized fruit crops (e.g. tomato, pepper) are sown in a nursery and then transplanted into the soilless growing system. Indeed, direct planting is preferable for vegetables like carrot, turnip, pea or bean to preserve the root structure.

Seedlings preparation in the nursery.

Sowing may be done in plastic or polystyrene trays with a substrate constituted by commercial soil added with perlite or expanded clay or other mixture of inert/organic substrates according to local availability. When the trays are ready, put one or more seeds in each hole. Then cover the seeds with a thin layer of substrate (planting depth depends on the species). Shade the trays and water them two times per day, never allowing the substrate to dry-up. After germination the trays are moved to the nursery where they still need protection from direct strong sun (shadow nets should reduce the sunlight incidence by 50%). At this stage, seedlings shall be watered with nutrient solution two times per day until transplanting, which occurs when seedlings present 4-5 true leaves.

Notes.

Seedlings quality is very important in order to achieve satisfactory

yield and shorten the plant cycle.

The first phases are the more delicate and require constant care, therefore some advices are:

1. Choose accurately the seeds. Prefer when possible old breeds and traditional cultivars;
2. Build the nursery in a good aerated area to avoid moisture stagnation and choose an area with good light;
3. Build the nursery nearby the garden in order to reduce climatic stresses after transplanting;
4. Wash the trays with sodium hypochlorite (1%) before sowing and dry them under the sun;
5. Scout frequently for fungus diseases or dangerous insects in the nursery, and be ready to intervene immediately;
6. Irrigation shall be properly programmed and efficient to avoid waterlogging;
7. It is good practice to use a foggy system in the nursery to reduce temperatures in the hottest hours of the day, during critically warm periods and months;
8. Avoid mechanical damage caused by big drops from the watering can on young seedlings, use sub-irrigation of the trays instead;
9. Keep internal and external areas of the nursery clean from weeds;
10. Reduce planting density soon after germination to avoid competition among the seedlings and leave only the more developed or vigorous in central position.

Transplanting seedlings in the soilless system

Transplanting is a very delicate phase. Root damage must be kept to a minimum. Wetting the trays before transplant will help to remove seedlings from the substrate, to maintain the plantlets turgid and consequently to reduce transplant shock. Plan transplant in order to avoid the hottest hours of the day (particularly critical during warm months). The seedlings need to be transplanted to good depth (species-specific) and the substrate has to be pressed gently around

the root system. Different species or cultivars have different cycle length from sowing to transplanting (Table 2).

/ Table 2. GENERAL INFORMATION ABOUT THE CYCLE LENGTH OF SELECTED VEGETABLES

Species	Planting and germination (days)	Period between Germination and transplant (days)	Transplant and harvest (days)
Lattuce	5	15-18	25-30
Tomato	6	18-22	65
Cucumber	10	15-18	40
Eggplant	10	20-25	75
Onion	10	30-35	80
Chives	10	30-35	55
Pepper	12	30-35	80
Cabbage	7	20-25	90
Cauliflower	7	20-25	75
Okra	3	15	35
Coriander	7	20-25	40

CROP MANAGEMENT ROUTINARY PROCEDURES



As a general principle, the garden maintenance should be performed once per year, in order to maintain the growing system fully operative.

Seasonal garden management

During spring, general maintenance is usually performed. In summer, in warmer climates, plants and water reservoirs may be shaded from direct sun radiation with shading net. This will also enable to avoid high nutrient solution temperatures. Weekly, EC and pH of the nutrient solution should be checked using a EC- and pH-meter and corrected accordingly.

Yearly garden management

At least one time a year the micro-garden system needs other care, like:

- the hydraulic timer should be removed during winter to avoid breakage due to ice formation;
- the substrate needs to be mixed with fresh one or fertilized;
- the hydraulic system needs to be washed. It is a good option to submerge drippers for 48 hours into a citric acid or vinegar water solution.

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