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Hydroponic Production of Fruit Tree Seedlings in Brazil

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1. Introduction

Fruit production is an important socio-economic activity in Brazil. Data from IBGE (2007) has shown 2 million and 260 thousand hectares and a production of approximately 41 million tons shipped with tropical, subtropical and temperate fruit. In this scenario orange, banana and coconut-the-bay productions deserve to be highlighted with 821,575 ha, 519,187 ha and 283,930 ha planted, respectively.

Hydroponics is the name given to all forms of cultivation in nutrient solution without using soil. The word hydroponics comes from two Greek words: hydro, water and ponos (from Greek), which means work. The combination of words means "work with the water," and implicitly, means the use of solutions and chemical fertilizers for growing plants in the absence of soil (Catellane & Araújo, 1994).

Hydroponic cultivation of plants is an ancient technique of cultivation. Plant growth in water is reported in hieroglyphic files dating hundreds of years before Christ, which describes the cultivation of plants in the River Nile. It is believed that the first use of hydroponic cultivation as a tool was in ancient Babylon, in the famous hanging gardens, known as one of the seven wonders of the ancient world (Prieto Martinez, 2006).

Woodward, in 1699, probably conducted the first experiments testing growing plants in liquid medium without the use of solid substrates. In 1804, Saussure made one of the first attempts to analyze the factors involved in growing plants in nutrient media, establishing the requirement to provide nitrogen in the form of nitrate to the solution of cultivation. In the nineteenth century intensive research were performed involving nutrient solutions and plant growth. Researchers like Sachs, Boussingault and Knop performed experiments with nutrient solution that helped to determine the essentiality of certain chemical elements for plant growth (Nachtigall & Dechen, 2006). Several formulations of culture solutions were developed, mainly from the elaboration growing solution of Hoagland & Arnon (1950).

The creation of the polymer polyethylene in 1930 and the technique of hydroponic cultivation known as Nutrient Film Technique (NFT) in 1965, created by the British Allen Cooper, enabled the use of hydroponics as a commercial scale (Prieto Martinez, 2006). Ever since, the commercial cultivation of vegetables, fruit, culinary medicinal and ornamental plants, using hydroponic techniques, have greatly expanded, especially near large urban centers.

Hydroponics is becoming a very interesting alternative compared to traditional farming cultivating on soil. It can be used in regions where there is limited availability of arable land and in regions where there was an excessive use of the soil, causing imbalance of chemical and biological characteristics, and high infestation of plant pathogens, frequent problems in protected cultivation. Thus, even in tropical countries with abundant land, hydroponics has been used quite successfully. In addition to the high capacity of production, independent of climate and soil conditions, hydroponics also offers high quality products and reduced use of pesticides when compared to the traditional cultivation in soil (Castellane & Araújo, 1995).

Each day, the natural resources like soil and water become scarce requiring new ways to rationalize their use. Nowadays, opening new agricultural frontiers is not feasible due to deforestation and concern for the environment. It is becoming increasingly necessary to enhance the productivity of different species of plants by breeding and/or by other techniques such as hydroponics that guarantees the preservation of natural resources like water and soil and increases the productivity.

The hydroponic cultivation has as main advantages the rational use of water and nutrients supplied to plants, so plants may present a further development in short time intervals. The rationalization of water use, perhaps is the most important feature, because population growth has been directly confronted with the limited water available for agricultural production systems (Zanini et al., 2002). The main advantages of hydroponics in addition to the water savings can be cited as: lower labor demand due to the higher automation system; elimination of operations with agricultural machinery such as plows and fences that harm the soil; has no need for crop rotation; increased productivity by up to three times compared to cultivation in the soil; reduced need for pest control due to reduced wetting of the leaf area; plant uniformity in the development and early production; better ergonomics for workers; and better utilization of nutrients by avoiding waste and leaching.

On the other hand, there are doubts about the effectiveness of hydroponics in order to have high initial cost and initial labor in setting up the structure; greater risk of loss in case of power outages in automated systems; require more knowledge and training of employees; greater risk of loss contamination with pathogens. These drawbacks can be easily circumvented by diluting the initial costs over the production cycles, simple staff training, installation of electrical generator, appropriate pathogen control, cleaning system with sodium hypochlorite and weekly monitoring of the structure.

The fruit trees are increasingly being investigated in hydroponics in order to produce quality fruit with low cost and preserving the environment. The use of hydroponic systems in these types of plants has been taken for some time to attend the consumer market by offering fresh fruit. However, when it comes to hydroponic systems for the production of fruit seedlings, the information is still very scarce. Many researchers have developed their research, but they are still not released due to patent applications, as can be evidenced in Faquin & Chalfun (2008) and Medeiros et al. (2000).

There are few published studies about producing fruit seedlings in hydroponics. The proposal for a hydroponic system to produce these plants has been studied by many researchers, since this is a method that saves water, labor, reduces the application of pesticides and allows the production of seedlings in less time compared to traditional systems in the field and screened nurseries.

Several studies have demonstrated the possibility of growing fruits in hydroponics as cited by Macedo et al. (2003) about pineapple cultivation, Costa & Leal (2008) about strawberry, Dechen & Albuquerque (2000) about grape and Villela et al. (2003) about melon and others crops.

2. Objective

The aim of this chapter is to present key information on the production of fruit seedlings in hydroponics and the main hydroponic systems used for this purpose.

3. Types of hydroponics and considerations about construction and management of hydroponics

3.1 Types of hydroponics

According to Furlani et al. (1999), the most common types of hydroponic system are:

a. NFT (nutrient film technique) or technique of laminar flow of nutrients. This system forms a layer of cultivation along the canals where plants, especially vegetables, keeps its roots. The technique allows wide range of adaptations and can be performed in rigid or flexible tubes with different sections, diameters and lengths (Figure 1 A);
b. DFT (deep technique film) or growing in water or floating or pool. In this system the nutrient solution establish a layer of 50 to 20 cm where the roots are submerged, with no channels of cultivation, but a flat table (Figure 1 D);
c. With substrate. This system utilizes pots, tubes, filled with masonry or other inert material such as sand, stones of diverse types, vermiculite, perlite, rockwool, phenolic foam and others compounds to support the plant. The nutrient solution is percolated through these materials and subsequently drained to the bottom of the container, returning to the solution tank for recirculation (Figures B and C).

The NFT system if compared to other hydroponic systems, presents as main advantages the lowest cost of install, easiness of operation and equipment sterilization between cultivation, saving water and nutrients due to the closed system for recycling and possible reduced environmental contamination with nutrients and pesticides from the effluent.

The hydroponic systems that employ the subirrigation can use substrates to sustain the plants or replace it with potted plants (Ebb and Flow System). In the most systems with substrates (Figures 1 B, C and D) is used sand, gravel, vermiculite and others (Table 1), since they have little or no chemical activity, so that the nutrition of plants depends entirely on the provision of a properly balanced nutrient solution (Prieto Martinez, 2006). The interest in systems that employ substrates has increased in recent years in order to reduce the number of fertigation and, consequently, the consumption of electricity (Andriolo et al., 2009).

Among the main advantages of subirrigation can be quoted to have uniform nutrition, good ventilation, easy anchoring of plants and more time for repairs in case of system failures. The disadvantages have been the largest cost of facilities and maintenance when compared with NFT.

The supply of nutrient solution by dripping is recommended for cultivation in substrates such as sand, perlite, sawdust, rice hulls, ground volcanic rock and mineral wool (Figure 1 B).

Fig. 1. Main types of hydroponics: A) NFT: one of the most used for growing hardwoods. This prototype uses fixed hardware and cultivation channels are double-sided facilitating the disinfection of the system; B) and C) Substrate: a system that allows the use of substrate with the nutrient solution percolation. It is also suitable for the production of fruit tree seedlings, D) DFT or Floating: a model suitable for production of seedlings of fruit trees. This example refers to the production of seedlings "Jenipapo" (*Genipa americana* L.) by using seeds. Source: Figures 1A, 1B e 1 C: Profa. Sheila Isabel do Carmo Pinto, Figure 1 D: IFMG Bambuí, Prof. Ricardo M. Corrêa.

Cultivation can be conducted in pots, mineral wool or plastic bags. Formerly these systems were open, however, the loss of water and nutrients, and the risk of environmental contamination with effluents led to the adoption of the circulating system. When passing through the substrate that composes the cultivation area, the nutrient solution composition has changed, beyond the incorporation of suspended solids; therefore the lixiviated should be filtered, disinfected and returned to a closed system (Prieto Martinez, 2006).

Among the advantages of farming systems by dripping can be cited the greater lateral movement of the nutrient solution and greater retention of moisture. However, the system has a higher cost of deployment and maintenance, mainly of the closed systems, and the difficulty of disinfecting after the cycles of cultivation and the possibility of obstruction of emitters (Prieto Martinez, 2006).

There are several options of substrates to be used in hydroponics, considering fruit crops were related vermiculite, sand and rice hulls (Table 1). However, there are possibilities of using other materials such as peat, cane bagasse, pruning waste, coconut fiber; it depends on availability, cost of these products in the region and properties (Table 2).

Mineral origin	Desirable characteristics	Difficulty	Finality	Reference
Vermiculite (mineral 2:1)	Free of pathogens	High cost, suffers breakdown along the crop cycles by reducing the aeration	Seedlings of peach, pear and tangerine Ponkan	Menezes 2010; Souza 2010
Perlite	Good drainage	-	Farming in general	No citation found for fruit
Rock wool	Good water retention, inert and easy to handle	Distribution of air and water disuniform	Depends on regional availability	No citation found for fruit
Phenolic foam	Easy acquisition and low cost	-	Production of vegetable seedlings	No citation found for fruit
Sand	Easy acquisition and generally inert	May contain high levels of calcium requiring care in the neutralization, for being heavy handling difficult	Absorption of macronutrients in grapevine rootstock; tolerance of grapevine rootstocks in saline	Albuquerque & Dechen (1997); Viana et al. 2001
Organic origin				
Cotton	Easy handling and lightweight	High cost	Farming in general	No citation found for fruit
Rail rice	Inert	High C / N ratio	Evaluation on strawberry varieties	Costa & Leal 2008; Fernandes Júnior et al. 2001
Pine bark / sawdust	Porosity and easy to purchase	Presence of phytotoxic substances when new, high C / N ratio	Farming in general	No citation found for fruit
Coconut fiber	Encourage germination, light, porous, easy to use and has low electrical conductivity	Depends on regional availability	Farming in general	No citation found for fruit
Peat	High water holding capacity and low density	High acquisition cost	Farming in general	No citation found for fruit
Foam castor	Not harmful for environment	Depends on regional availability	Farming in general	No citation found for fruit

Table 1. Materials that can be used for hydroponic cultivation on substrate. Source: Adapted from Bliska Junior, 2008 & Andriolo, 1999.

Property	Substrate							
	Sand	Gravel	Expanded clay	Vermiculite	Mineral wool	Coconut fiber	Polyurethane foam	Phenolic foam
TVP(1) (%)	38-44	42	69-72	-	95	95-96	>95	> 95
Water retention capacity	Moderate/High	Low	Low	High	High	Low	High	High
Soil aeration	Low/Moderate	Moderate	Moderate/High	Moderate	Moderate/High	High	High	Moderate
Diameter (mm)	0,2-2,0	2,0-20,0	4-20	0,75-8,0	-	0,5-2,0	-	-
Density (kg m3-)	High (1500)	High (1530)	Moderate (500-600)	Low 96-160	Low <100	Low (56-75)	Low (55)	Low (10-25)
Capillary action	Moderate	Low	Low	High	High	-	-	-
Water loss by evaporation	Moderate	Moderate	Moderate	High	High	-	-	-
Loss of structure	Low	Low	Low	Moderate	Moderate	Low	No	High
Reusability	Good	Good	Good	Good	Unusual	Unusual	No	No
pH	4,0-8,0	6,9	5-7	5,5-9,0	7,0-8,5	4,9-5,6	6,0-9,0	6,0-7,5
CEC(2) (cmolc dm3-)	Low (0,3-0,5)	Low (0)	Low (0-0,2)	High (5,0)	Low 0-0,1	-	Low	Low

(1)TVP: total pore volume; (2)CEC: cation exchange capacity.

Table 2. Main properties of the substrates used in hydroponic systems. Adapted from Martinez Prieto (2006).

In the DFT-type systems a bench containing a blade of 5 to 10 cm of water is used, where trays or tubes are displaced in direct contact with the nutrient solution (Fig. 1 D), and irrigation done by capillary . The reservoir level is usually flushed where the excess solution flows through a pipe at a lower level being conducted into a reservoir where it is recirculated. However, this system requires a lot of water and good aeration system. In the seedlings production of woody species as the most fruit trees, DFT or hydroponics substrates seems to be more efficient because these plants are difficult for large-scale management and staking in NFT system. Most of the data about fruit trees seedlings has used the DFT or substrates as cited by Menezes (2010) & Souza (2010).

Each substrate has its own characteristics that must be known (Table 1), evaluating their suitability for the crop system and to the culture to be produced. In the choice of substrate should be considered: cost, availability, stability over time and absence of toxins and / or pathogens. The main chemical and physico-chemical characteristics of the substrate that should be assessed are: decomposition rate, pH, buffer capacity, cation exchange capacity (CEC), electrical conductivity, sodium concentration, density and water retention (Prieto Martinez, 2006). In Table 2 the main characteristics of the substrates can be observed.

The literature cites several hydroponic systems listing many advantages and disadvantages. According to Menezes (2010) most systems are dynamic, and there is forced circulation of water or air to oxygenate the solution. It is observed that there is a tendency to use the NFT system, Mitchell & Furlani (1999) report that this trend is due to factors such as more effective control of nutrition, reduced cost and easiness in the renewal of crop fields. However, it was observed in the present review, the tendency to use floating systems and substrates for fruit crops.

3.2 Considerations about construction and management of hydroponics

To consider a hydroponic system efficient it should combine low cost, high production of plants or seedlings, suitable nutrient solution for the species cultivated, as well as hydraulic structure appropriate for the proper functioning of the system.

The seedlings of fruit bearing herb may be performed using NFT systems, sub-irrigation in bed with substrate or Ebb and Flow system or drip. The cultivation of seedlings for shrub fruit (citrus, guava, peach, grape, etc.) is better suited to the cultivation system by sub-irrigation Ebb and Flow System, since due to the need for better anchoring of these plants should be grown potted and is more common to use tubes. The use of tubes in the production of seedlings of fruits makes transplanting them into the field, as well as possible damage to the root system during handling (Figure 1 D).

To build a hydroponic system the producer can use simple materials and even materials for recycling. Usually small producers that own little capital can acquire low-cost materials such as treated wood, vases, bottles, scrap wood and others. The reservoir of nutrient solution, depending on the number of seedlings being produced, can be water-tower of 250, 500, 1000 L or more, but should not exceed 5.000 L (due the complicated management of the solution). The use of asbestos water tank should be avoided due to release of chemical compounds in the nutrient solution.

In contrast, currently there are numerous opportunities in the market of companies that lead all construction projects of greenhouses and hydroponic systems. There is a huge variety of equipment that enables the system to automate the most productivity.

To calculate the reservoir volume of nutrient solution should be considerate the number of plants that intended to grow, ranging from 0.1 L up to 5 L. In the case of production of fruit plants that are of larger size is recommended volumes around 3-5 L^{-1} plant. Whether the goal is to produce 500 seedlings, for example, should be planned a reservoir of 2,500 L. It is noteworthy that large reservoirs (bigger than 5,000 L) complicate the management of the solution and it is recommended to mount systems in series with several smaller reservoirs. If happens contamination of the solution and loss of seedlings, the damage is minor.

The place where will be accommodate the motor-pump set must be as fresh as possible to avoid heating the solution. In general the reservoir can be buried in the soil to or build masonry to keep the tank and electrical system that support the pump and timer. In tropical locations the temperature in solution can be very high reaching 104º F, which enables the cultivation. In this sense, especially in warm regions the accommodation of the nutrient solution reservoir should be correctly kept (Figure 2 A).

Fig. 2. Detail of the pump house (under construction) illustrating: A) Hydroponics being built by focusing the detail of water tank buried in the soil to avoid heating, B) and C) Set motor pump installed in a primed (below the level of reservoir), D) Panel containing outlet, timer relay and nutritious species. Photos: IFMG Bambuí, Professor Ricardo M. Corrêa.

The circulation of the nutrient solution is usually done in the NFT system from 15 to 15 minutes during the day and during the night this interval may be increased to 30 to 60 minutes due to lower evapotranspiration. This caution must be taken and the system monitored throughout the day especially when the temperatures are very high, since the lack of water can cause death of plants.

Electrical conductivity is another point that should be well monitored, because it measures the amount of salt added to solution. The solution must be renewed periodically to avoid problems in plant growth. Furlani (1997) recommends renew the solution every month. According to this author, the renewal avoids unnecessary accumulation of components presents in the water not absorbed by plants, and the excess of organic material from decomposed algae and roots, which contribute to the development of microorganisms harmful to plants. In general the conductivity varies between species, 1.4 to 3.0 mS cm-1 depending on the plant size, nutritional requirements and types of drains as fruits, tubers and other.

After each cycle of cultivation it is important to clean the solution reservoir with hypochlorite to reduce algae growth. After cleaning it follows by the renewal of water and dilution of the salts according to the recommendation of the species of nutrient solution.

4. Propagation and fruit seedlings production in hydroponic

4.1 Fruit propagation

The propagation methods can be grouped into two types: sexual propagation, which is based on the use of seeds and asexual propagation, based on the use of vegetative structures. Fundamentally, the difference between the two forms of propagation is the occurrence of mitosis and meiosis. While asexual propagation the cell division involves the simple multiplication (mitosis), keeping unchanged the number of chromosomes, in sexual propagation meiosis provides a reduction in the number of chromosomes (Fachinello et al. 2005). In field or in greenhouse plants can be propagated asexually by cuttings, grafting, layering, through other structures such as stolons, bushes and saplings. The use of seeds in fruit cultivation is more restricted to the formation of rootstocks and breeding, with the exception of papaya and coconut that still rely on seeds to produce seedlings. The current trend in the production of seedlings of fruit trees is to work with asexual propagation in order to maintain the characteristics of the genotype, reduce the period of growing the seedling in the nursery and a consequent cost reduction as well as reduce the juvenile period and size.

Tissue culture is a biotechnological tool that allows obtaining large number of plants in limited time and with high quality plant. However, micropropagation protocols are more developed for herbaceous species such as strawberry, banana and pineapple, while occur more difficulty to growth in vitro woody fruit.

In an in vitro culture one of the techniques researched that still had little advance was the micrografting which consists of micrografts under aseptic conditions, a stem apex, containing two to three leaf primordia, excised from a mother plant on a rootstock established in vitro (Adapted from Peace & Pasqual, 1998). However, due to the difficulty of growing woody species in vitro and the process of micrografting be cumbersome, this technique still goes in slow steps.

Among the methods of asexual propagation, the most used are cuttings, layering and grafting (Simão, 1998), and for some fruit like strawberries and bananas are used more specific methods such as stolons and division of clumps, respectively. The layering is a process that can be divided into soil layering and air layering (or layering). According to Gomes (2007), the soil layering is rarely used for fruit trees propagation. However, air layering is more applicable in the production of fruit mainly lyche and jaboticaba.

4.2 Hydroponics cultivation of fruit

Usually most fruit trees are grown in the field due to the need for large areas of cultivation, a soil support to maintain the plant, water, nutrients and also space for canopy growth. Over the years, researchers began to notice that not only leafy vegetables can be grown in hydroponics, but also species such as fruit vegetables as pepper, paprika, cucumber and tomato (Furlani and Morais, 1999, Rocha et al., 2010) , seed potatoes (Medeiros et al., 2002, Correa et al., 2009, Correa et al., 2008), fruits such as strawberries and melon (Furlani & Morais, 1999; Andriolo et al. 2009; Fernandes Júnior et al ., 2001), pineapple (Macedo et al. 2003); Vilela Junior et al., 2003), coffee (Tomaz et al., 2003), eucalyptus and pine (Wendling et al. 2003; Loewe & Gonzalez, 2003) among others.

The hydroponic culture requires special care in installation and conduction of the culture. The plants growth and formation with commercial quality depend on the production of good seedlings. For this, some factors should be considered, such as variety to be cultivated, seed source, substrate to be used, place of germination, seedling growth and management of the nursery (Paulus et al., 2005).

Obtaining seedlings begins with selecting the seeds, which should have been properly collected, processed, stored, packaged, free of pathogens and pelleted (Prieto Martinez, 2006). Cultivation of plants such as strawberry, melon, watermelon, pineapple and other is held by producers to attend the trade. The seedlings to sustain these crops are made in the field or greenhouse conditions with generally high levels of pests and diseases.

Strawberry and melon plants have growth habits similar to the vegetables and, in this way, they are commonly cultivated in hydroponics where the management is facilitated due the small size of plants. However, considering fruit trees and woody plants such as orange, peach, apple, avocado, there are other restrictions and difficulties of cultivation for commercial production due to the size and weight. But hydroponics can assist in the production of woody seedlings species since the short period of time to be taken to the field.

The production of seedlings to support commercial crops is usually done in the field or greenhouse. The greenhouse crops are being most preferred due to the high phytosanitary control mainly in tropical regions that provide greater proliferation of pests and diseases. The fruit seedlings production in hydroponic cultivation is an alternative to soil cultivation and can reduce the number of applications of pesticides, prevent spread of pests and diseases, increase the efficiency of water use, reduce waste, nutrients, enabling early harvests and reduce time of seedling production.

Fachinello & Bianchi (2006) report the importance of seedlings quality influencing productivity of orchards. These same authors state that to compete in today's market fruit, it is necessary to produce with quality and competitive price. According to those authors, the productivity of orchards is seriously compromised by infection of plants by viruses and similar organisms.

Currently many producers have installed a screen against aphid and countertops held to prevent entry of insects and disease proliferation. In this sense, the hydroponic systems can be deployed in those screened maximizing the quality of producing seedlings in less time.

Souza (2010) reports that the production of pear and peach seedlings in hydroponics is considered unprecedented, becoming a new way to produce seedlings of fruit trees of temperate climates. According to him the production of seedlings in hydroponics has been used in a pioneering way, due to its early production and absence of pathogens, especially related with the soil.

Hydroponics emerges with a viable alternative for the production of fruit seedlings, because this culture system stimulates the production of high number of seedlings per m^2, beyond plant seedlings of high quality, attending an increasingly demanding market. Thus, the use of hydroponics for the production of citrus plants, using conventional methods of propagation, may be a promising activity (Mehta, 2010).

Among different studies developed, the propagation method initially more used in hydroponics was grafted due to be one of the most widely used in fruit growing. Table 3 shows some references about some fruit species such as pear, peach, mandarin Ponkan, pineapple and guava. Some of these studies are under patent and details of the hydroponic nutrient solution were not disclosed.

Fruit bowl	Type of hydroponics	Nutrient solution	Propagation	Reference
Pear (*Pyrus calleryana* Decne	Floating	Not disclosed (patent in process)	Grafting	Souza (2010)
Peach (*Prunnus persica* L. cv. Okinawa)	Floating	Not disclosed (patent in process)	Grafting	Souza (2010)
Tangerine (*Citrus reticulata*)	Floating	Not disclosed (patent in process)	Grafting	Menezes (2010)
Pyrus communis cv. 'Triunfo', 'Tenra' e 'Cascatense'	Floating	Not disclosed (patent in process)	Grafting	Souza et al. (2010)
Pineapple (*Annanas comosus* L. Merrill var. Perola	Floating	1/5 of Hoagland and Arnon solution (1950)	Micropropagation and termination of the seedlings in hydroponics	Macedo et al. 2003
Guava (*Psidium guajava* L. cv. Paluma and cv. Século XXI)	Aeroponic	Test solutions of Hoagland & Arnon (1950); Sarruge (1975); Castellane & Araujo (1995); Furlani et al. (1999)	Propagation of seedlings of guava	Franco and Prado (2006)

Table 3. Seedlings of fruit species grown in hydroponics.

5. Nutrient solutions, substrate and management

A nutrient solution can be defined as a homogeneous system where the nutrients needed by plants are scattered, usually in ionic form and proportion.

Besides nutrients, it is assumed that the nutrient solution containing oxygen and proper temperature to the absorption of nutrients by the plants. However, it should be noted that in any system of soilless culture, two important factors on productivity should be observed: the environment, determined by the type of plant protection, especially the cover with transparent plastic films and fabrics for shading, and nutrient solution, which can be free or dispersed in a substrate (Cometti et al., 2006).

The secret of success in hydroponics is not the sophistication of the materials used in the construction of greenhouses and the system itself. The success in hydroponics is reached when it combines low cost assembly, market demand for the product to be produced, type of hydroponic system used, place of location the hydroponic system, nutrient solution and its management and prevention the system against crashes, besides skill labor.

Among the recommendations mentioned above, the nutrient solution is noteworthy since the food that plants need are the nutrients that depend on the amount and availability of these plants. According to Malavolta (2006) there are several aspects to consider about the mineral requirements of crops, which generally apply to all species: (1) total requirements, (2) amounts in harvested product, (3) amounts for the production unit, (4) requirement in the cycle, (5) needs in the agricultural year, (6) reserves mobilization, (7) accumulation in the fruit, (8) cycling. In this sense, the energy that will be demanded during the propagation process, such as emission of roots (in the case of cutting and layering) and growth of shoots (in the case of grafting) depend on the availability of mineral nutrients that must be available at the right time and quantities required. Thus, correct nutrient solution, balanced, correct pH and well managed contributes to the production of seedlings be successful.

The composition of the nutrient solution has been studied for many years, with reports dating to 1865, as the Knopp solution. However, only after 1933 there were concerns about the preparation of a solution containing micronutrients. In 1938, Hoagland & Arnon showed a complete and balanced nutrient solution for tomato, based on the composition of plants grown in pots with nutrient solution (Hoagland & Arnon, 1950). In 1957, this solution was slightly adapted with respect to $NO3_-$: $NH4^+$ by Johnson et al. (1957), to keep pH close to five. From the solution of Hoagland and Arnon, many others have been developed, such as Clark (1975), but the traditional solution of "Hoagland" remains the most used (Cometti et al., 2006).

Initially a lot of research with fruit adopt nutrient solutions already developed for other species, which are already standardized (Table 4). Dechen & Albuquerque (2000) studied the absorption of macronutrients by rootstocks and grapevine cultivars in hydroponics. These authors based the solution of macronutrients on Furlani (1995) and micronutrients on Hoagland & Arnon (1950). It was observed high vigor of rootstocks 'Jales' (IAC 572), 'Tropical' (IAC 313) and 'Campinas' (IAC 766) with high correlation between amount of biomass and nutrients accumulated.

It must be admitted, however, that there is not an ideal nutrient solution to cultivate all crops, since there is a variation depending on various factors such as species, plant developmental stage, time of year, environmental factors, among others. In theory any plant that grows naturally in the soil can be grown in hydroponics, i.e. small species, shrubs, herbaceous plants such as vegetables, ornamental, medicinal and others (Crocomo, 1986). For the production of fruit seedlings like shrubs, the nutrient solutions used are still in research stage and are not published in scientific journals, since the production technology of these plants are going through the process of establishing patent.

In this sense, Franco and Prado (2006) found difficult to compare the results of their research to the literature due to lack of information about the nutrient solution for fruit, especially guava. These authors stated that there are no studies indicating an ideal solution for growing seedlings of guava, and the comparison of results with the literature is impaired.

Macedo et al. (2003) succeeded in terminating pineapple plants derived from in vitro propagation. These authors used a solution of Hoagland & Arnon (1950) diluted in 1 / 5 and concluded that the seedlings produced in the laboratory were more developing ex vitro, using the floating hydroponics. This is another applicability of hydroponics in the acclimation of seedlings, since the micropropagated plants instead of being in acclimatized on conventional nursery with waste water and nutrients can be adopted as the floating hydroponic systems or substrate for acclimatization. All plants from tissue culture must be acclimatized before going to the field and hydroponics can be an alternative to traditional nurseries.

The management of nutrient solution should be very careful done, considering that the absorption of nutrients and water occurs in different proportions, which is a challenge to

Nutrient solution	**Composition (mg L-1)**	**Fruiter**	**Finality**	**Reference**
Hogland & Arnon (1950)	210,1 (N); 31,0 (P); 234,6 (K); 200,4 (Ca); 48,6 (Mg); 64,1 (S); 0,5 (B); 0,02 (Cu); 0,65 (Cl); 5,02 (Fe); 0,5 (Mn); 0,01 (Mo); 0,05 (Zn)	Pineapple, Guava	Acclimatization of micropropagated plants, production of seedlings	Macedo et al., 2003; Franco & Prado, 2006
Castelane & Araújo (1994)	200 (N); 40 (P); 150 (Ca); 133 (Mg); 100 (S); 0,3 (B), 2,2 (Fe); 0,6 (Mn); 0,3 (Zn); 0,05 (cu) e 0,05 (Mo)	Melon	Production of melon	Costa et al., 2004
Bernardes Júnior et al. (2002)	102,62 (N); 40 (P); 116 (K); 36,16 (S); 76 (Ca); 27 (Mg); 1,89 (Fe); 0,55 (Mn); 0,32 (B); 0,20 (Zn); 0,08 (Cu); 0,02 (Mo)			
Furlani et al. (1999)	202,0 (N); 31,5 (P); 193,4 (K); 142,5 (Ca); 39,4 (Mg); 52,3 (S); 0,26 (B); 0,04 (Cu); 1,8 (Fe); 0,37 (Mn); 0,06 (Mo); 0,11 (Zn)	Guava	Seedling production	Franco & Prado, 2006

Table 4. Some of the major nutrient solutions used in hydroponic fruit.

Index	Good	Acceptable	Maximum
EC(1) mS cm^{-1}	< 0,75	0,75 - 1,50	2,0
pH	6,50	6,80	7,50
Na^+ mmol L^{-1}	0,87	1,30	2,61
Ca^{2+} mmol L^{-1}	6,5	10,00	14,00
Cl^- mmol L^{-1}	1,14	1,71	2,86
SO_4^{2-} mmol L^{-1}	0,83	1,26	2,08
Fe µmol L^{-1}	-	-	0,08
Mn µmol L^{-1}	-	-	0,04
Zn µmol L^{-1}	-	-	0,02
B µmol L^{-1}	-	-	0,03

(1)EC: electrical conductivity. Adapted of Prieto Martinez (2006) and Böhme (1993).

Table 5. Quality indices used for water used in hydroponic systems.

proper nutrient replenishment and water. Water used to prepare the nutrient solution must be quality (Table 5), free of contaminants and excess chlorine.

Martinez Prieto (2006) points out that maintaining a favorable environment for plant growth depends on choice, preparation and maintenance or adjustment of the solution as the plants grow. It is essential the continuous monitoring of nutrient solution, correcting, where necessary, the volume of water, pH and nutrients concentration.

The concentration of nutrients can be monitored by measuring the electrical conductivity of the nutrient solution, being used as an indicator of the need for replacement or exchange it. However, it should be noted that the electrical conductivity of nutrient solution is not a quantitative measure of the nutrients present in the solution, but only the concentration of ions in the medium and this may vary due to changes in temperature of the solution.

The pH of the nutrient solution should be adjusted daily, as this varies depending on the differential absorption of cations and anions by plants. High concentrations of H^+ in the nutrient solution can destabilize the cell membranes, causing loss of ions and death of cells of the root. The plants can withstand a pH between 4.5 and 7.5 without major physiological effects. However, indirect effects, such as a reduction in nutrient availability, may seriously compromise the growth of plants, since changes in pH may promote the formation of ionic species that are not readily transported to the cells, impairing the absorption of nutrients (Cometti et al., 2006).

The choice of substrate depends on their physical and chemical characteristics and requirements of the species used for rooting (Verdonck et al., 1981). The substrate affects not only the quality of roots formed, as well as in the percentage of rooting of cuttings (Couvillon, 1988), having also the function of fixing them and keep the environment on the basis of the them, wet, dark and with adequate aeration (Fachinello et al., 1994). The physical relationship between volume of water and air present in the substrate influences the morphology of adventitious roots formed and its branches (Wilson, 1983). The techniques used to produce seedlings in hydroponics adopt different substrates for rooting cuttings. Depending on the type of substrate used, the rooted cuttings may show non-uniformity of adventitious roots, reflecting the fixation and plant development (Paulus et al., 2005). You should opt for those that do not convey pathogens, which are uniform, lightweight, low cost, easy to disinfect to allow re-use, high moisture retention and good aeration, and in the case of transplanted bare root, easily release from the roots. Substrates that adhere to the roots and are difficult to remove lead to a greater stress in transplanting, delaying recovery and resumption of plant growth, and its permanence in the system could promote blockages (Prieto Martinez, 2006).

The temperature is another factor to be considered, since high temperatures of the greenhouses can impair the development of seedlings, causing a reduction in growth rate and areas of necrotic tissue in the leaves and stem. These symptoms occur due to starvation, in the other words, breathing more than photosynthesis, and it becomes worse when the humidity is excessive, because the needs of oxygen for root respiration and an accumulation of toxic products such as ethanol or acetaldehyde (Martinez Prieto, 2006).

It should be emphasized the importance of providing adequate amounts of light and nutrients in the formation of seedlings. Insufficient environmental heatstroke can result in etiolated seedlings with low rate between root / shoot and the excess can cause damage to seedlings. The nutrition of the seedlings must be balanced to provide nutrients in appropriate quantities and proportions, since the substrates normally used in hydroponic systems, have low or no chemical activity.

Barboza et al. (1997) studying pear rootstocks "Taiwan Nascher-C" in field conditions in plastic bags with 5 L of soil observed that the time for 65% of the rootstocks reached the point of grafting was 240 days of growth. However, Souza (2010) could produce these same rootstock to 77 days, 163 days in anticipation of using the hydroponic substrate. That is, in hydroponics were spent only 32% less time in relation to the field for rootstocks in grafting point. Consequently, there is significant cost reduction in producing pear seedlings.

For peach Raseira & Medeiros (1998) studied under field conditions rootstocks 'Okinawa' in 5 L plastic bags containing soil and obtained plants able to the graft 240 days after sowing, in hydroponic conditions. Souza (2010) has reduced for 69 days the formation time of the same rootstock. These data showed that the formation of peach rootstock in hydroponics takes approximately 29% less time spent than in field conditions.

Franco et al. (2007) studied the growth and mineral absorption of nutrients for seedlings of guava. These authors used a solution of Castellane and Araujo (1995) that according to Franco and Prado (2006) was the solution recommended for the guava tree. Franco et al. (2007) concluded that there is an accumulation of dry matter of guava plants along the time of growing and cultivating and the seedlings of Century XXI have greater demand for macronutrients than seedlings of the cultivar Paluma.

At IFMG Bambuí Campus are being driving and testing the system of hydroponics where DFT pools were built measuring 1.2 m wide by 2.2 m in length. These DFT pools contain media with tubes of various kinds of substrates such as bagasse cane, vermiculite and pine bark, shredded pruning waste, among others. These tubes are inserted into various materials such as seeds and propagating cuttings of several species such as guava (*Psidium guajava* L.), loquat (*Eriobotrya japonica* Lindl.), Surinam cherry (*Eugenia florida* DC.) and genipap (*G. americana* L.) (data not published). The adaptability of these species have been observed in pre-tests and further tests will be conducted to study different substrates and methods of propagation of fruit trees (Figure 3).

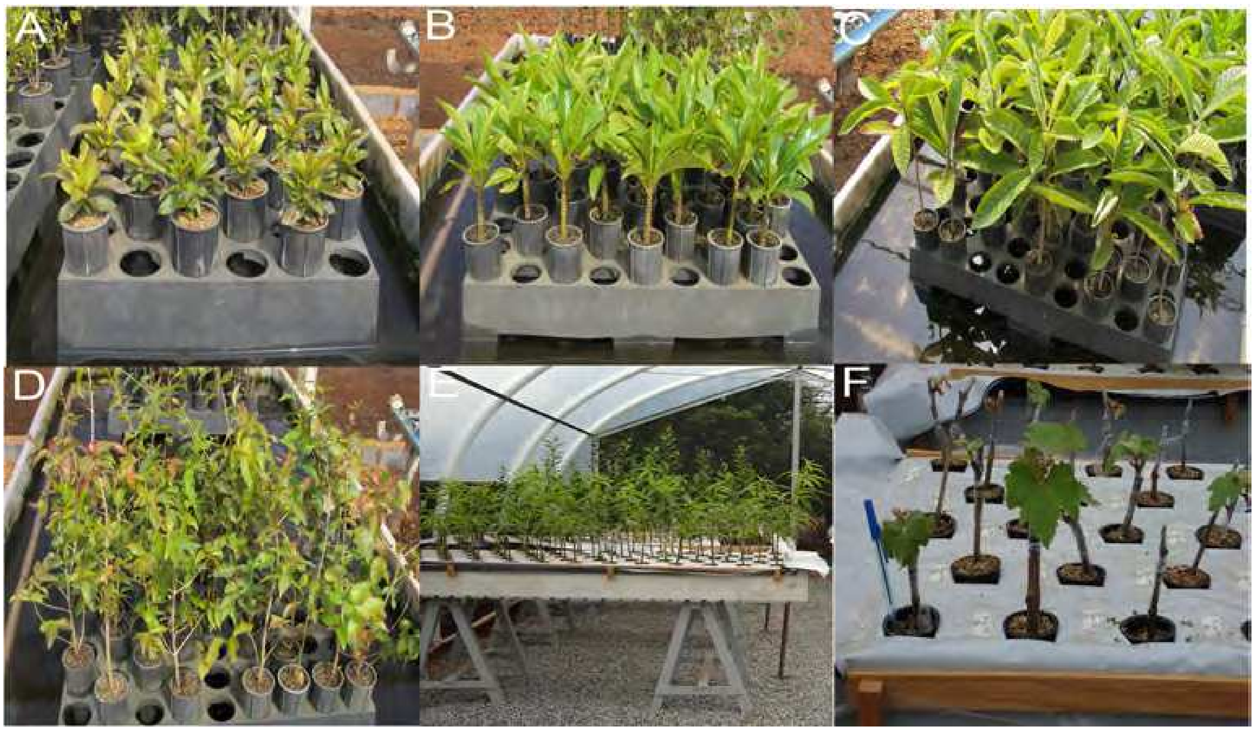

Fig. 3. Some possibilities for the production of fruit tree seedlings in hydroponics: A) Guava (*P. guajava* L.), B) Jenipapo (*G. americana* L.), C) Loquat (*E. japonica* Lindl.), D) Pitanga (*E. florida* DC.) E) Peach (*P. persica* L.), and F) Grape (*V. vinifera* L.). Source: Figures 1 A, 1 B, 1 C and 1 D: Professor Ricardo M. Correa. Figures 1 E and F: Courtesy of Prof. Josinaldo Lopes Araujo (Federal University of Paraíba, Brazil).

Therefore, hydroponics depends on skilled labor since any change in plants or in the system can compromise the production. The professionals who deal with hydroponics must know technical details about the species to be produced, plant health problems and how to fix them, symptoms of nutrient deficiency and toxicity, management of nutrient solution, anticipation of possible power outages and the consequent lack of water circulation in the channels, among other skills. In this sense, it is necessary to qualify the employee responsible of conducting hydroponics.

6. Proposal for a hydroponic system for the production of grape seedlings

A simple system is proposed in Figure 4 to obtain grape seedlings in plastic tubes using the DFT system. Initially should be prepared a wooden box of 2.2 m long by 1.2 wide and 25 cm high and then cover it with plastics double-sided with the white side facing up so it will waterproofs them. Later trusses are posted on this other side of the plastic. The following is drilling holes along the surface of the plastic tubes for accommodation of the tubes. These tubes are usually of average size of 6 cm wide and 19 cm in height comprising 280 cm^3 of substrate. Smaller tubes are not recommended because they have lower volume of substrate and commitment of the root system. The rootstocks are rooted in advance before being placed in this hydroponic system. After accommodation of grape rootstocks in the pool, the process of grafting is executed. After this process it is observed the success of the graft and subsequent growth of the seedling.

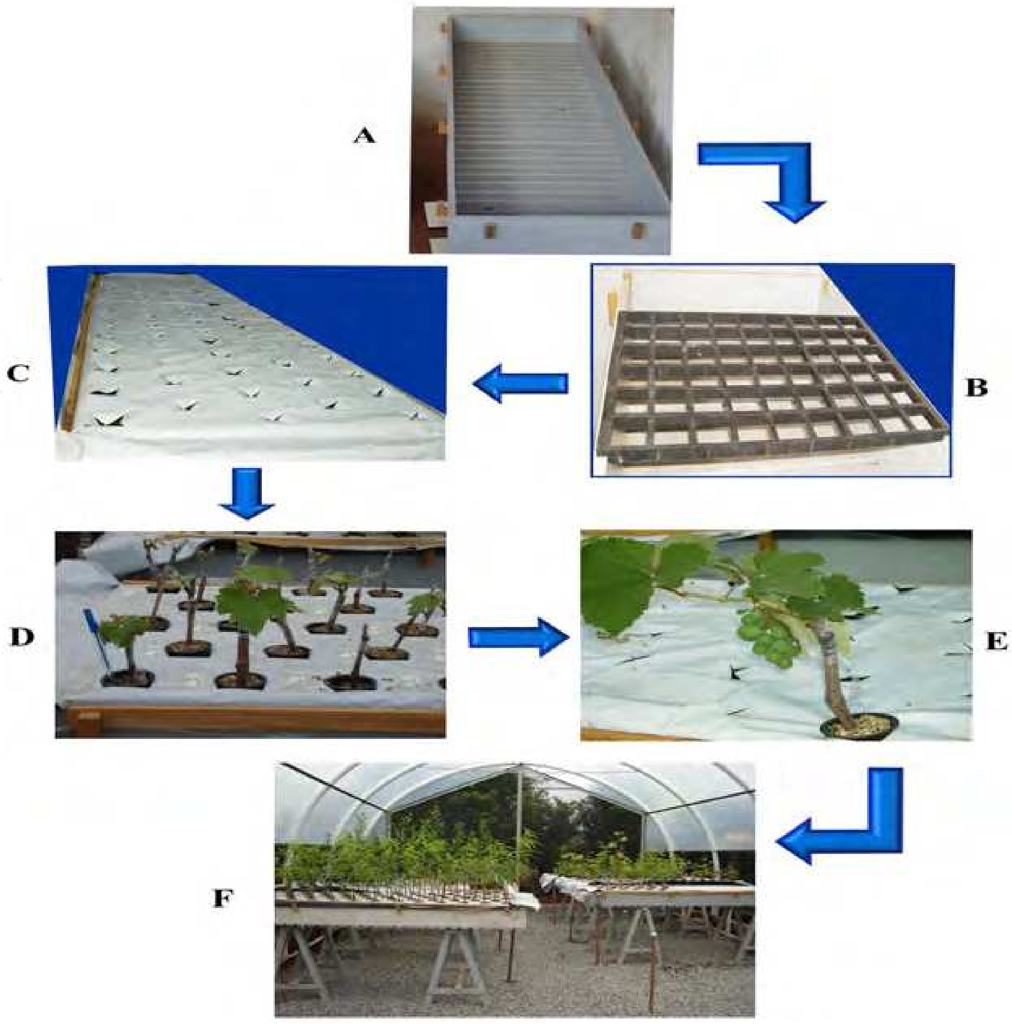

Fig. 4. Sequence assembly of hydroponic system to produce seedlings of fruit trees. (A) Support of wood that will hold the nutrient solution and the seedlings of fruit trees, (B) Truss to support the wooden support and sustain the tubes with the seedlings, (C) Support of wood completely covered with plastic to receive the nutrient solution and prevent the entry of light in the nutrient solution to avoid the proliferation of algae, (D) seedlings grown in hydroponic vine, (E) vine seedlings produced hydroponically presenting precocious fruit production, (F) seedlings of different species of fruit produced in hydroponic systems. Photos: Courtesy of Prof. Josinaldo Lopes Araujo (Federal University of Paraíba - Brazil).

7. Final considerations

Hydroponics is promising to produce fruit tree seedlings, but still needs research that guide to a better production system and for hydroponic nutrient solution that attend the needs of each species. Results from literature are scarce and discuss briefly the production of seedlings of woody plants such as orange, guava, grape, mango among other important.

The nutrient solutions used by the researchers are still based on the others developed for different kinds of vegetables such as lettuce, tomatoes and potatoes. However there is no record of a specific nutrient solution developed specifically for fruit, but it is under a patent process.

Future research should be conducted trying to identify a substrate, a hydroponic nutrient solution and an ideal hydroponic system for each fruit species combining low cost and profitability.

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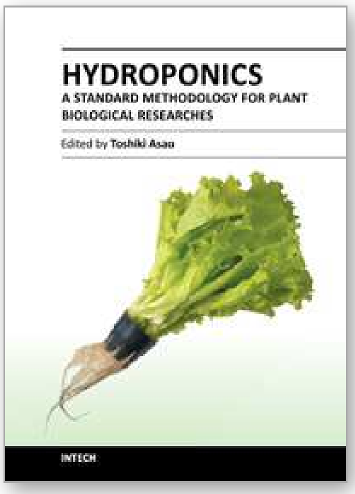

Hydroponics - A Standard Methodology for Plant Biological Researches
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Hydroponics-A standard methodology for plant biological researches provides useful information on the requirements and techniques needs to be considered in order to grow crops successfully in hydroponics. The main focuses of this book are preparation of hydroponic nutrient solution, use of this technique for studying biological aspects and environmental controls, and production of vegetables and ornamentals hydroponically. The first chapter of this book takes a general description of nutrient solution used for hydroponics followed by an outline of in vitro hydroponic culture system for vegetables. Detailed descriptions on use of hydroponics in the context of scientific research into plants responses and tolerance to abiotic stresses and on the problems associated with the reuse of culture solution and means to overcome it are included. Some chapters provides information on the role of hydroponic technique in studying plant-microbe-environment interaction and in various aspects of plant biological research, and also understanding of root uptake of nutrients and thereof role of hydroponics in environmental clean-up of toxic and polluting agents. The last two chapters outlined the hydroponic production of cactus and fruit tree seedlings. Leading research works from around the world are brought together in this book to produce a valuable source of reference for teachers, researcher, and advanced students of biological science and crop production.