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Significance of Soilless Culture in Agriculture

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1.1 HISTORICAL FACETS OF SOILLESS PRODUCTION

Although we normally think about soilless culture as a modern practice, growing plants in containers aboveground has been tried at various times throughout the ages. The Egyptians did it almost 4000 years ago. Wall paintings found in the temple of Deir el Bahari (Naville 1913) showed what appears to be the first documented case of container-grown plants (Fig. 1.1). They were used to transfer mature trees from their native countries of origin to the king's palace and then to be grown this way when local soils were not suitable for the particular plant. It is not known what type of growing medium was used to fill the containers, but since they were shown as being carried by porters over large distances, it is possible that materials used were lighter than pure soil.

Starting in the seventeenth century, plants were moved around, especially from the Far and Middle East to Europe to be grown in orangeries, in order to supply aesthetic value, and rare fruits and vegetables to wealthy people. An orangery is 'a sheltered place, especially a greenhouse, used for the cultivation of orange trees

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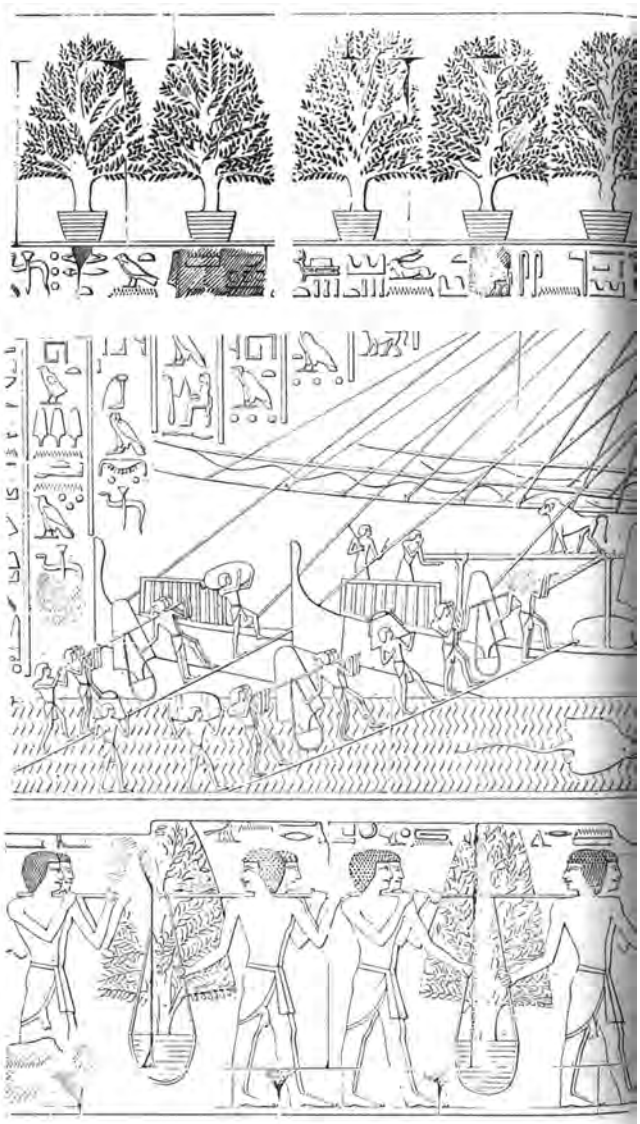

FIGURE 1.1 Early recorded instance of plant production and transportation, recorded in the temple of Hatshepsut, Deir el-Bahri, near Thebes, Egypt (Naville, 1913; Matkin et al., 1957).

in cool climates' (American Heritage Dictionary), so it can be regarded as the first AU1 documented case of a greenhouse container-grown system, although soil was mostly used to fill these containers. Orangeries can still be found today throughout Europe. AU2 An exquisite example from Moscow, Russia, is shown in Figs. 1.2A and 1.2B.

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FIGURE 1.2A Orangery in Kuskovo, Moscow (1761–1764) (see also Plate 1; with kind permission of photographer Alexei Troshin and Wikipedia – The Free Encyclopedia, http://en.wikipedia.org/wiki/Image:Kuskovo_orangerie.jpg).

FIGURE 1.2B The orangerie at Pillnitz Palace near Dresden, Germany (see also Plate 2).

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The orangerie at Pillnitz Palace near Dresden Germany was used to protect container-grown citrus trees during the winter. Large doors at the east side allowed trees to be moved in and out so that they could be grown outdoors during the summer and brought inside during the winter. Large floor-to-ceiling windows on the south side allowed for sunlight to enter.

As suggested by the name, the first plants to be grown in orangeries were different species of citruses. An artistic example can be seen in Fig. 1.3.

Two major steps were key to the advancement of the production of plants in containers. One was the understanding of plant nutritional requirements, pioneered by French and German scientists in the nineteenth century, and later perfected by mainly American and English scientists during the first half of the twentieth century. As late as 1946, British scientists still claimed that while it is possible to grow plants in silica sand using nutrient solutions, similarly treated soil-grown plants produced more yield and biomass (Woodman and Johnson, 1946 a,b). It was not until the 1970s that researchers developed complete nutrient solutions, coupled their use to appropriate rooting media

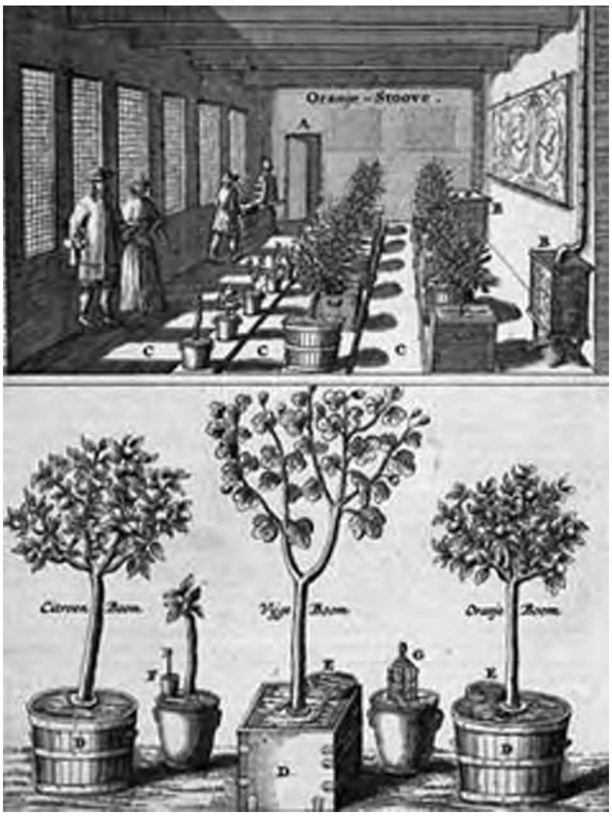

FIGURE 1.3 Orangery (from *The Nederlanze Hesperides* by Jan Commelin, 1676).

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and studied how to optimize the levels of nutrients, water and oxygen to demonstrate the superiority of soilless media in terms of yield (Cooper, 1975; Verwer, 1977).

The second major step was the realization that elimination of disease organisms that needed to be controlled through disinfestation was feasible in container-grown production while being virtually impossible in soil-grown plants. In the United States, a key document was the description of a production system that provided a manual for the use of substrates in conjunction with disease control for production of container-grown plants in outdoor nursery production. Entitled *The U.C. System for Producing Healthy Container-grown Plants through the use of clean Soil, Clean Stock, and Sanitation* (Baker, 1957), it was a breakthrough in container nursery production in the 1950s and 1960s and helped growers to such an extent that it became universally adopted since growers using the system had a dramatic economic advantage over competitors that did not use it. This manual described several growing media mixes consisting of sand and organic matter such as peat, bark or sawdust in various specific percentages (Matkin and Chandler, 1957). These became known as 'UC mixes'. It should be noted that in this manual these mixes are called 'soil' or 'soil mixes', largely because prior to that time most container media consisted of a mix of soil and various other materials. That convention is not used in this book; here we treat the term 'soil' as meaning only a particular combination of sand, silt, clay and organic matter found in the ground. Thus, when we talk about soilless substrates in this book, they may include mineral components (such as sand or clay) that are also found in soil, but not soil directly. The term 'compost' was also used as a synonym to 'soil mix' for many years, especially in Europe and the United Kingdom (Robinson and Lamb, 1975), but also in the United States (Boodley and Sheldrake, 1973). This term included what is now usually termed 'substrate' or 'growing medium' and, in most cases, suggests the use of mix of different components, with at least one of them being of organic origin. In this book, we use the term 'growing medium' and 'substrate' interchangeably.

These scientific developments dispelled the notion that growing media can be assembled by haphazardly combining some soil and other materials to create 'potting soil'. This notion was supported in the past by the fact that much of the development of ideal growing media was done by trial and error. Today we have a fairly complete picture of the important physical and chemical characteristics (described in Chaps. 3 and 6, respectively), which are achieved through the combination of specific components (e.g. UC mix) or through industrial manufacture (e.g. stone wool slabs).

Throughout the world there are many local and regional implementations of these concepts. These are generally driven by both horticultural and financial considerations. While the horticultural considerations are covered in this book, the financial considerations are not. Yet this factor is ultimately the major driving force for the formulation of a particular substrate mix that ends up in use in a soilless production setting. The financial factor manifests itself through availability of materials, processing costs, transportation costs and costs associated with production of plants/crops as well as their transportation and marketing. Disposal of used substrates is, in some cases, another important consideration of both environmental and economical implications. For example, one of the major problems in the horticultural use of mineral wool

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(stone- and glass-wool) is its safe disposal, as it is not a natural resource that can be returned back to nature. Various methods of stone-wool recycling have been developed but they all put a certain amount of financial burden on the end-user.

In countries where peat is readily available, perhaps even harvested locally, growers find this material to be less expensive than in countries where it has to be imported from distant locations. As prices of raw materials fluctuate, growers must evaluate whether to use a 'tried and true' component (e.g. peat) or a replacement (e.g. coconut coir) in a recipe that may have proven to work well over the years. In some years the financial situation may force consideration of a change. Since the properties of all substrates and mixes differ from each other, replacement of one particular component (such as peat) with another component might result in other costs or lower quality crops (which may be valued less in the market place), especially if the substitution is a material with which the grower has less experience. Thus growers throughout the world face the challenge of assembling mixes that will perform as desired at the lowest possible overall cost.

The result of this is that the substrates used throughout the world differ significantly as to their make-up, while attempting to adhere to a specific set of principles. These principles are quite complex, relating to physical and chemical factors of solids, liquids and gasses in the root zone of the plant.

Today the largest industries in which soilless production dominates are greenhouse production of ornamentals and vegetables and outdoor container nursery production. In urban horticulture, virtually all containerized plants are grown without any field soil.

1.2 HYDROPONICS

Growing plants without soil has also been achieved through water culture without the use of any solid substrates. This type of soilless production is frequently termed 'hydroponics'. While this term was coined by Gericke (1937) to mean water culture without employing any substrate, currently the term is used to mean various things to various persons. Many use the term to refer to systems that do include some sort of substrate to anchor or stabilize the plant and to provide an inert matrix to hold water. Strictly speaking, however, hydroponics is the practice of growing plants in nutrient solutions. In addition to systems that use exclusively nutrient solution and air (e.g. NFT, DFT, aerohydroponics), we also include in this concept those substrate-based systems, where the substrate contributes no nutrients nor ionic adsorption or exchange. Thus we consider production systems with inert substrates such as stone wool or gravel to be hydroponic. But despite this delineation, we have in this book generally avoided the use of the term 'hydroponics' due to the fact that not every one agrees on this delineation.

Initially scientists used hydroponics mainly as a research tool to study particular aspects of plant nutrition and root function. Progress in plastics manufacturing, automation, production of completely soluble fertilizers and especially the development of many types of substrates complemented the scientific achievements and brought

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soilless cutivation to a viable commercial stage. Today various types of soilless systems exist for growing vegetables and ornamentals in greenhouses. This has resulted with a wide variety of growing systems; the most important of these are described in Chap. 5.

1.3 SOILLESS PRODUCTION AGRICULTURE

World agriculture has changed dramatically over the last few decades, and this change continues, since the driving forces for these changes are still in place. These forces consist of the rapid scientific, economic and technological development of societies throughout the world. The increase in worlds' population and the improvement in the standard of living in many countries have created a strong demand for high-value foods and ornamentals and particularly for out-of-season, high-quality products. The demand for floricultural crops, including cut flowers, pot plants and bedding plants, has also grown dramatically. The result of these trends was the expanded use of a wide variety of protected cultivation systems, ranging from primitive screen or plastic film covers to completely controlled greenhouses. Initially this production was entirely in the ground where the soil had been modified so as to allow for good drainage. Since the production costs of protected cultivation are higher than that of open-field production, growers had to increase their production intensity to stay competitive. This was achieved by several techniques; prominent among these is the rapid increase in soilless production relative to total agricultural crop production. AU3

The major cause for shift away from the use of soil was the proliferation of soil-borne pathogens in intensively cultivated greenhouses. Soil was replaced by various substrates, such as stone wool, polyurethane, perlite, scoria (tuff) and so on, since they are virtually free of pests and diseases due to their manufacturing process. Also in reuse from crop to crop, these materials can be disinfested between so as to kill any microorganisms. The continuing shift to soilless cultivation is also driven by the fact that in soilless systems it is possible to have better control over several crucial factors, leading to greatly improved plant performance.

Physical and hydraulic characteristics of most substrates are superior to those of soils. A soil-grown plant experiences relatively high water availability immediately after irrigation. At this time the macropores are filled with water followed by relatively slow drainage which is accompanied by entry of air into the soil macropores. Oxygen, which is consumed by plant roots and soil microflora, is replenished at a rate which may be slower than plant demand. When enough water is drained and evapotranspired, the porosity of the soil is such that atmospheric oxygen diffuses into the root zone. At the same time, some water is held by gradually increasing soil matric forces so that the plant has to invest a considerable amount of energy to take up enough water to compensate for transpiration losses due to atmospheric demand. Most substrates, on the other hand, allow a simultaneous optimization of both water and oxygen availabilities. The matric forces holding the water in substrates are much weaker than in soil. Consequently, plants grown in porous media at or near container capacity require less energy to extract water. At the same time, a significant fraction of the

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macropores is filled with air, and oxygen diffusion rate is high enough so that plants do not experience a risk of oxygen deficiency, such as experienced by plants grown in a soil near field capacity. This subject is quantitatively discussed in Chap. 3 and its practical translation into irrigation control is described in Chap. 4.

Another factor is that nutrient availability to plant roots can be better manipulated and controlled in soilless cultivation than in most arable soils. The surface charge and chemical characteristics of substrates are the subjects of Chap. 6, while plant nutrition requirement and the methods of satisfying these needs are treated in Chap. 8. Chapter 7 is devoted to the description of the analytical methods, used to select adequate substrate for a specific aim, and other methods, used to control the nutritional status during the cropping period, so as to provide the growers with recommendations, aimed at optimizing plant performance.

Lack of suitable soils, disease contamination after repeated use and the desire to apply optimal conditions for plant growth are leading to the worldwide trend of growing plants in soilless media. Most such plants are grown in greenhouses, generally under near-optimal production conditions. An inherent drawback of soilless vs. soil-based cultivation is the fact that in the latter the root volume is unrestricted while in containerized culture the root volume is restricted. This restricted root volume has several important effects, especially a limited supply of nutrients (Dubik et al., 1990; Bar-Tal, 1999). The limited root volume also increases root-to-root competition since there are more roots per unit volume of medium. Chapter 2 discusses the main functions of the root system while Chap. 13 quantitatively analyses the limitations imposed by a restricted root volume. Various substrates of organic origin are described in Chap. 11, while Chap. 12 describes substrates of inorganic origin and the issue of potting mixes. In both the chapters, subjects such as production, origin, physical and chemical characteristics, sterilization, re-use and waste disposal are discussed.

Container production systems have advantages over in-ground production systems in terms of pollution prevention since it is possible, using these growing systems, to minimize or eliminate the discharge of nutritional ions and pesticide residues thus conserving freshwater reservoirs. Simultaneously, water- and nutrient-use efficiencies are typically significantly greater in container production, resulting in clear economic benefits. Throughout the developed countries more and more attention is being directed to reducing environmental pollution, and in the countries where this type of production represent a large portion of agricultural productivity, regulations are being created to force recirculation so as to minimize or eliminate run-off from the nurseries and AU4 greenhouses. The advantages and constraints of closed and semi-closed systems in an area that is currently seeing a lot of research and the state-of-the-art is described in Chap. 9. The risk of disease proliferation in recirculated production and the methods to avert this risk are described in Chap. 10.

The book concludes with a chapter (Chap. 13) dealing with operational conclusions. In many cases practitioners are treating irrigation as separate from fertilization, and in turn as separate from the design and creation of the substrate in which the plants are grown. This chapter addresses the root-zone as a dynamic system and shows how such a system is put together and how it is managed so as to optimize crop production, while

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at the same time respecting the factors imposed by society (run-off elimination, labour savings, etc.). Another subject which is mentioned in this chapter is the emerging trend of 'Organic hydroponics' which seems to gain an increasing popularity in some parts of the world.

One of the main future challenges for global horticulture is to produce adequate quantities of affordable food in less-developed countries. Simple, low-cost soilless production systems may be part of the solution to the problems created by the lack of fertile soils and know-how. The fact that a relatively small cultivated area can provide food for a large population can stimulate this development. This, in turn, should stimulate professionals to find alternatives to current expensive and high-tech pieces of equipment and practices, to be suitable and durable for the needs of remote areas. One of the most important advantages of soilless cultivation deserves mentioning in this context: in most of the developing countries water is scarce and is of low quality. By superimposing the FAO's hunger map (Fig. 1.4) on the aridity index map (Fig. 1.5), it is clear that in many regions of the world such as sub-Sahalian Africa, Namibia, Mongolia and so on, a large part of the population suffers hunger mainly due to water scarcity. Since water-use efficiency of soilless plant production (and especially in recirculated systems) is higher than that of soil-grown plants, more food can be

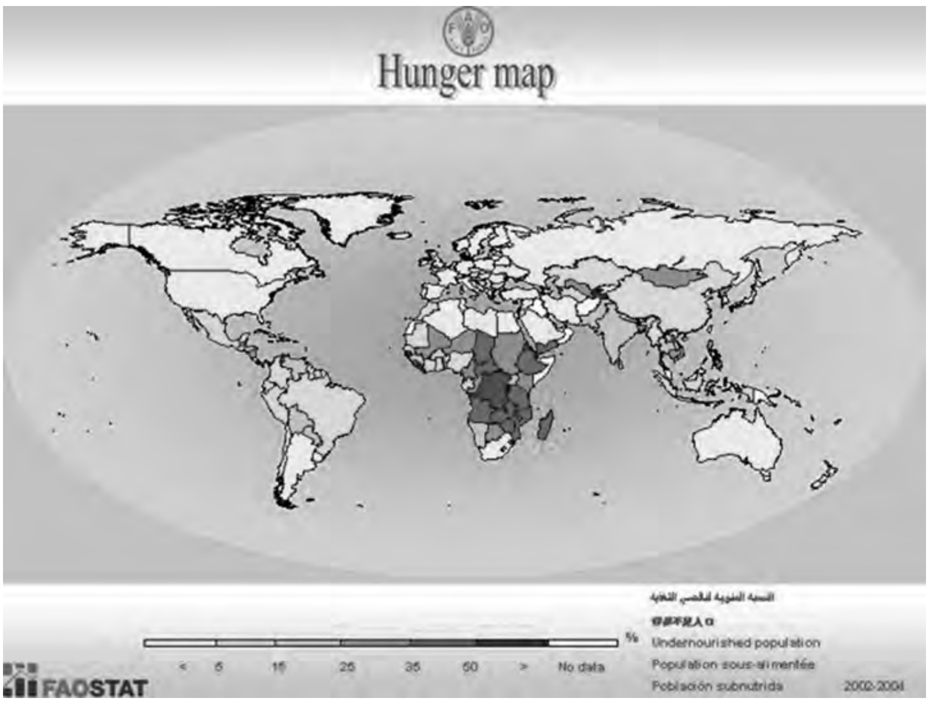

FIGURE 1.4 Percentage of undernourished population around the globe (see also Plate 3; with kind permission of the FAO).

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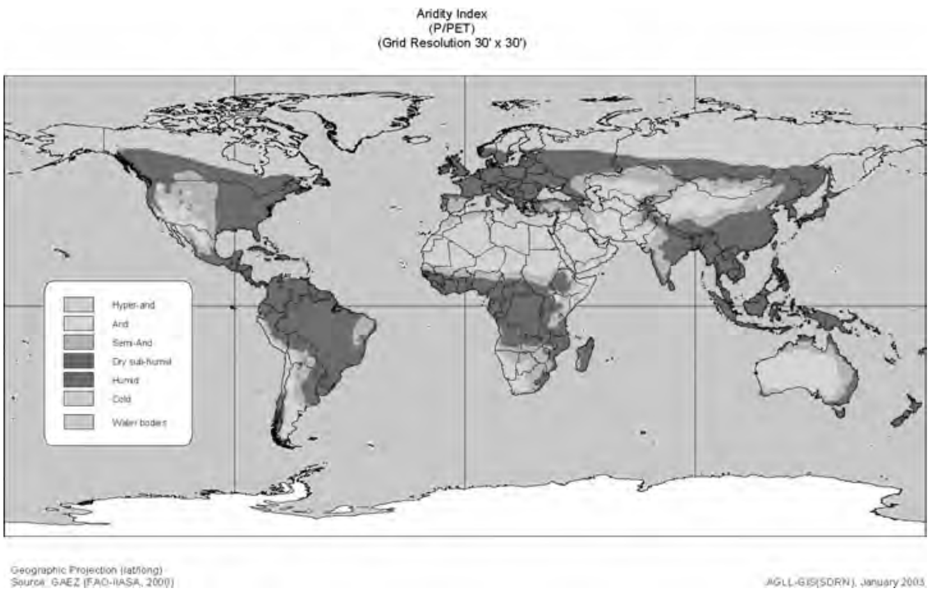

FIGURE 1.5 Aridity index around the globe (see also Plate 4; with kind permission of the FAO).

produced with such systems with less water. Also, plants growing in such systems can cope better with higher salinity levels than soil-grown plants. The reason for this is the connection between ample oxygen supply to the roots and their ability to exclude toxic ions such as Na^+ and to withstand high osmotic pressure (Kriedemann and Sands, 1984; Drew and Dikumwin, 1985; Drew and Lauchli, 1985). It is interesting to note, in this respect, that soilless cultivation is practised in large scale in very arid regions AU5 such as most parts of Australia, parts of South Africa, Saudi Arabia and the southern part of Israel. In none of these countries, hunger is a problem.

The science of plant production in soilless systems is still young, and although much work has been done, many questions still remain unanswered. One of the purposes of this book is to focus on the main issues of the physical and chemical environment of the rhizosphere and to identify areas where future research is needed so as to take further advantage of the available substrates and to propose desirable characteristics for future substrates and growing practices to be developed by next generation of researchers.

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This chapter explains soilless culture and describes its significance in agriculture. It begins with a historical account of facets of soilless culture in agriculture, suggesting that substrates used throughout the world differ significantly as to their make-up, while attempting to adhere to a specific set of principles. These principles are quite complex, relating to physical and chemical factors of solids, liquids, and gasses in the root zone of the plant. 1 Center Laboratory for Agriculture Climate (CLAC), Agriculture Research Center, P.O.Box 296 Imbaba, 12411, Giza, Egypt. 132 Journal of Agriculture and Environmental Sciences, Vol. 3(4), December 2014.Â Generally roots in soilless culture are usually exposed daily to large variations in temperature while deep penetrating roots of soil grown plants can escape. 138 Journal of Agriculture and Environmental Sciences, Vol. 3(4), December 2014.Â significance as compared with other treatments. The roots of cucumber plant had higher growth in the media with Biochar and HS treatment due to improved porosity and lower bulk density compared with other treatments, thus reducing the root resistance to growth in this cultures media. (ALTLAND 2006 and CHAN et al. Related Searches for soilless culture: indian cultural items culture bacterial juice culture bacteria culture corporate culture botryococcus braunii cultures chinese culture tissue culture souvenir cheese culture urine culture animal cell culture cultural promotional items rubber culture More Sign In Join Free. My Alibaba. My Alibaba Message Center Manage RFQ My Orders My Account.Â Â·Â·Â· < Sponsored Listing Tags: Black Craft Culture Slate | Tissue Culture Jar | Seri Culture Equipments. hydroponics system soilless culture on hot sale. US $15-20 / Square Meter. 100 Square Meters (Min.