RECENT ADVANCES IN HYDROPONICS PRODUCTION OF HORTICULTURAL CROPS: A REVIEW

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ABSTRACT

Horticulture is a fast growing major sector of the agricultural industry in most developing countries especially in Africa. Its contribution towards small-scale and large-scale farm incomes, employment opportunities, foreign exchange earnings, and food production has experienced unprecedented growth in recent years. A major problem in growing crops on farm land is soil-borne diseases. Growing plants continuously, without crop rotation or interruption in production as in open field production can lead to an excessive build-up of soil pathogens and pests. Because of environmental and health concerns, effective fumigants like methyl bromide use is restricted or is prohibited outright in most countries. This problem, added to the high cost of fuel for steam sterilisation of soil, calls for focusing more attention on controlled environment agriculture. Recently, there has been increasing interest in hydroponics or soilless techniques for producing greenhouse horticultural crops. The principal advantages of hydroponics culture include high-density planting, maximum crop yield, crop production where no suitable soil exists, more efficient use of water and fertilisers, and minimal use of land area. Hydroponics production systems are installed in greenhouses, ensuring year round production, and use less water as compared to conventional production systems. Low agricultural productivity in most developing countries has been attributed to limited availability of irrigation water, inadequate irrigation infrastructure, and high dependence on rain-fed agriculture. Hydroponics horticultural production can be seen as one of the mitigation measures in increasing food production and farm income in developing countries. Hydroponics production technology will contribute to reduction in water utilisation in horticultural production, utilisation of land in areas of little or no agricultural potential, engagement of farmers in horticultural production the year round and reduction of pesticide usage in horticultural production.

INTRODUCTION

The distinction between hydroponics and soilless culture of plants has often been blurred. Soilless culture is a broader term than hydroponics; it only requires that no soils with clay and silt are used. Note that sand is a type of soil, yet sand culture is considered a type of soilless culture. Hydroponics is always soilless culture, but not all soilless culture is hydroponics (Anon., 2007a).

Hydroponics is the growing of plants without soil (Dan, 2007). It can also be defined as the science of growing plants using a solution of suitable nutrients instead of soil (Hydroponics Gardening Information, 2007). This can either be through the use of non-soil growing medium or no growing medium at all. The plants thrive on the nutrient-water solution alone. The growing medium, if any, is totally inert and merely acts as a support for the plants and their root systems, while the solution passes freely (Anon., 2006). The hydroponics gardener replaces the soil with a balanced, nutrient-rich solution that the plant can absorb with ease (Hydroponics Gardening Information, 2007). Terrestrial plants may be grown with their roots in the mineral nutrient solution only, or in an inert medium, such as perlite, gravel or rockwool (Anon., 2007a). Conventional plant growth relies on plants absorbing minerals and nutrients from soil. Plants do not actually need to be placed in soil to obtain the nutrients they need. In fact the soil is simply there to support them (Anon., 2007a).

There are many rocky areas on earth, which have no soil to support plant growth, preventing humans from living there. Over the years, this restriction has been combated by growing plants hydroponically. Growing food hydroponically is a fascinating process, making commercial sense for many growers who are now able to produce on a large scale without enormous land investment (Dan, 2007).

DEVELOPMENT OF HYDROPONICS TECHNOLOGY

The earliest recordings of hydroponics in use were in the Hanging Gardens of Babylon where plants were grown in a steady stream of water (InfoHub, 2008). Hydroponics has been used for over a century as a research technique, but not until 1929 where experiments were conducted solely to determine its feasibility for growing commercial crops (Infoplease, 2007). With the first successful application of hydroponics techniques in the 1930's, the stage was set for a paradigm shift in crop production from conventional cultivation in soil to soilless cultivation (Parera, 2009). The first crops to be commercially grown in hydroponics included tomato and pepper. Nowadays, virtually any plant can be grown hydroponically, but some will do better than others. Hydroponics growing is ideal for fruit vegetables like tomato, cucumber, squash, and pepper; leafy vegetables like lettuce, herbs and broccoli; legumes like peas and beans as well as ornamental plants (Fresh From The Garden, 2007; InfoHub, 2008).

During World War II, the US army used hydroponics to grow fresh tomato and lettuce for troops stationed on infertile lands on the Pacific Islands (Anon., 2009a; InfoHub, 2008). By the 1950's, there were viable commercial farms operating in USA, Britain, Africa, and Asia (InfoHub, 2008). In 1981, rockwool was used in Australia for the hydroponics culture of cut flowers (InfoHub, 2008). Hydroponics technology can be used to generate food crops from almost anywhere, including the Artic, city roof-tops, barren deserts sand, space stations, and where land is very expensive (The Hydroponics Gardening, 2009).

THE SIGNIFICANCE OF HYDROPONICS IN MODERN AGRICULTURE

Although hydroponics is possible for most plant species, a limiting factor is the amount of physical support required. There are several different types of hydroponics systems, but all share the same basic method of supplying the plants with nutrients and water. Hydroponics is perhaps the most intensive method of crop production in today's agricultural industry (Jensen, 2008). It uses advanced technology, it is highly productive, conserves water and land, protects the environment but is often capital intensive. Since regulating the aerial and root environment is a major concern in such agricultural systems, production takes place inside enclosures that give control of air and root temperature, light, water, plant nutrition and protection against adverse climatic conditions.

Hydroponics offers opportunities to provide optimal conditions for plant growth and therefore, higher yields can be obtained using it compared to open field production (Anon, 2008b). It offers a means of control over soil-borne diseases and pests, which is especially desirable in the tropics where the life cycles of these organisms continue uninterrupted and so do the threat of infestation. Thus the costly and time-consuming tasks of soil sterilisation, soil amelioration etc. can be avoided with hydroponics cultivation (National Gardening Association, 2008; Jensen, 2008).

Under hydroponics, some plants can be grown closer together than in the field because roots are directly fed; thereby increasing yields per unit area and multiple cropping can be practised. Plants grow faster because they get all the nutrients they need in the proper amounts and proportions. In soil, plants develop a large root system to enable them search for nutrients and water. In hydroponics, nutrients and water are provided directly to the roots. This enables the plants to achieve higher growth of the shoot system, producing more vegetation, larger fruits, flowers and other edible parts. In addition to conserving space, hydroponics almost eliminates weed and soil-pest problems (Infoplease, 2007). Plants in hydroponics grow up to two times faster with higher yields than with conventional soil farming methods due to high oxygen levels to the root system, optimum pH levels for increased nutrient and water uptake, and optimum balanced and high grade nutrient solutions (Fresh From The Garden, 2007; Infoplease, 2007; SharmanShop, 2007).

In rapidly changing world of hydroponics technology, yields higher than never realised before are possible. Consistent efforts have been made to develop simple, labour- and cost-efficient hydroponics systems (Schnitzler *et al*., 2004). Hydroponics growing systems have been developed to get higher yield and quality, to preserve water and land, to save labour and to protect the environment through reduced use of pesticides. Important advantages of hydroponics culture, especially the closed systems, are the excess nutrient solution is recovered, management and reduction of waste material, less pollution of ground water and surface water, a more efficient use of water and fertilisers, the buffer capacity of for making mistakes and lower costs (Inden and Torres, 2004).

HYDROPONICS SYSTEMS

There are several different types of hydroponics system, but all share the same basic method of supplying the plants with nutrients and water. The hydroponics systems include:

1. Water culture, solution culture, aquaculture or nutri-culture: This is a system in which the plant roots are immersed in water containing a complex mixture of dissolved nutrients. This system may include static solution culture, where plants are grown in containers of nutrient solution, such as buckets, tubs or tanks. The solution may be aerated or unaerated. If unaerated, the solution level is kept low enough that enough roots are above the solution. Clear containers are covered with aluminium foil, black plastic etc., to exclude light, which facilitates growth of algae and moss (Anon., 2007a; Anon., 2007b; Hydroponics Gardening Information, 2007; Jensen, 1999);
2. Aggregate culture: In this system, a solid, inert material such as peat, vermiculite, or a combination of both, coconut coir, sawdust, sand, gravel, rockwool, diahydro, expanded clay, perlite, brick shards and polystyrene or marbles supports the plant roots (Hydroponics Gardening Information, 2007; Hydroponics Gardening Information, 2007; Infoplease, 2007; SharmanShop, 2007). It is important to note that the support material, unlike soil, does not absorb nutrients. It merely traps it in the spaces between the grains or stones allowing the plant roots to freely take up the liquid. The nutrient solution is delivered directly to the plant roots. Aggregate systems may be either open or closed, depending on whether surplus amounts of the solution are to be recovered and reused. Open systems do not recycle the nutrient solutions, however, closed systems do. In most open hydroponics systems, excess nutrient solution is recovered, however, the surplus is not recycled to the plants, but is disposed of in evaporation ponds or used to irrigate other plants. Because the nutrient solutions are not recycled, such open systems are less sensitive to the composition of the medium used or the salinity of the water (Hydroponics Gardening Information, 2007; Infoplease, 2007; Jensen, 1999);
3. Continuous flow system: In these systems, the nutrient solution flows constantly over the plant roots. This is the most commonly used for commercial production. A popular variation to this system is the Nutrient Film Technique (NFT). The NFT allows for constant flow of nutrient solution over plant roots. It is most commonly used for commercial production. In NFT the plants grow through light-proof plastic films placed over shallow, gentle sloping channels. A steady flow of nutrient solution is maintained along the channel and the roots grow into dense mats, with a thin film of nutrient passing over them. Plants are planted through holes in a flexible plastic material that covers each trough. Nutrient solution is pumped to the higher end of each channel and flows by gravity past the plant roots to catchment pipes and a sump (Hydroponics Gardening Information, 2007; Infoplease, 2007; Hydroponics Gardening Information, 2007; Jensen, 1999; Jensen, 2008);

4. Aerobics: This system is one in which the plant roots hang in the air and are misted or fogged regularly with a nutrient solution. This system minimises water usage as well as giving the roots ample access to oxygen (Anon., 2007a; Anon., 2007b; Hydroponics Gardening Information, 2007; Jensen, 1999);
5. Flood and drain (or ebb and flow system): A tray is placed on top of the nutrient solution. The tray is either filled with growing medium and planted directly, or pots of medium stand in the tray. At regular intervals, a simple timer causes a pump to fill the upper tray with nutrient solution, after which the solution drains back down into the reservoir. This keeps the medium regularly flushed with nutrient and air (Anon., 2007a; Anon., 2007b; Hydroponics Gardening Information, 2007; Jensen, 1999);
6. Top irrigation: In this system, nutrient solution is periodically applied to the medium surface. This may be done manually once per day in large containers of some medium, such as sand. Usually automated with a pump, timer and drip irrigation tubing to deliver nutrient solution as frequently as 5 to 10 minutes every hour (Anon., 2007a; Anon., 2007b; Hydroponics Gardening Information, 2007; Jensen, 1999);
7. Deep flow hydroponics: The classic hydroponics system, where plants are supported so that their roots hang into a nutrient solution. This system is appropriate for hobbyist and large-scale commercial production of leafy vegetables. The system consists of horizontal, rectangular-shaped tanks lined with plastic. The nutrient solution is monitored, replenished, recalculated, and aerated (Anon., 2007a; Anon., 2007b; Hydroponics Gardening Information, 2007; Jensen, 1999); and
8. Bag culture system: In this system, the growing medium is placed in plastic bags which are placed on the floor in the greenhouse. Light coloured bags should be used in hot climates in order to reflect radiation and inhibit over-heating of growing medium and dark coloured ones in cold climates to absorb heat especially in winter (Jensen, 2008). Growing media for bag culture include peat, vermiculite, or a combination of both to which polystyrene beads, small waste pieces of polystyrene or perlite to reduce the total cost (Jensen, 2008). Bags can be sealed on both ends and placed horizontally. Holes are made in the upper surface of each bag for the introduction of the transplants. Two small slits are made on the lower side to allow for drainage or leaching. Less commonly, the bags are placed vertically with open tops for single-plant growing. Vertical bags have the disadvantage that they are less convenient to transport, require more water and maintain less moisture (Jensen, 2008). Drip irrigation of the nutrient mix, with a capillary tube leading from the main supply to each plant, is recommended. The most common plants grown in bag culture are tomato (*Lycopersicon esculentum* Mill.), cucumbers (*Cucurbita sativas* L.) and cut flowers (Jensen, 2008).

The advantages of hydroponics culture include: solution culture hydroponics allows greater control over the root zone environment than soil culture; hydroponics is best crop production method in remote areas that lack suitable soil, such as Antarctica, space stations, deserts etc.; soil borne diseases are virtually eliminated;

weeds are virtually eliminated; edible crops are not contaminated with soil; water use can be substantially less than with outdoor irrigation of soil-grown crops; hydroponics systems give the plants more nutrition while at the same time using less energy and space; hydroponics allows for easier fertilisation as it is possible to use an automatic timer to fertilise the plants; plant density may be increased per unit of growing area compared to field; yield per plant is usually increased; and hydroponics plants grow faster than field grown ones (Anon., 2007a; Brechner, 2007). The disadvantages of hydroponics culture include: if timers and electric pumps fail or the system clogs, plants can die very quickly; hydroponics requires a greater technical knowledge; since most hydroponics are found in the greenhouse, crops are usually more expensive than soil grown crops; plants require to be supported because roots have no anchorage without solid medium; and the plants will die if not frequently monitored while soil plants do not require such attention (Anon., 2007a; Brechner, 2007).

MEDIA USED IN HYDROPONIC SYSTEMS

Various growing media can be used in hydroponics systems. However, any medium must have the following four qualities: sufficient support for the plants; maximum water availability for the plant roots; accessible nutrient solution with consistent chemical characteristics; provide good aeration to the roots; provide a sterile environment free of pests and disease pathogens; should be inert substrate that will not release elements to the plant roots; it must retain good structural integrity without decomposing; and it must have good water retention, but not excessive that could cause inadequate aeration.

Different media are appropriate for different growing techniques. They include:

1. Diahydro: Natural sedentary rock medium. It consists of the fossilised shells of algae (diatoms) that lived millions of years ago. It is extremely high in silica (87–94%), an essential component for growth of plants and strengthening of cell walls;
2. Expanded clay: Also known as ‘hydroton’ or ‘leca’. It consists of small, round baked spheres of clay, which are inert and suitable for hydroponics systems in which all nutrients are carefully controlled in water solution. The clay is formed into round pellets and fired in rotary kilns at 1200^{o}C. This causes the clay to expand, like popcorn, and become porous. It is light in weight and does not compact in time. It can be cleaned and sterilised for reuse;
3. Rockwool: It’s the most widely used medium in hydroponics. It is made from basalt rock, that is heated at high temperatures then spun back together like candy floss. It comes in different forms including cubes, blocks, slabs, and granulated flock;
4. Coir: It is derived from coconut husk fibre, which is usually compressed;
5. Perlite; It is a volcanic rock that has been superheated into very lightweight expanded glass pebbles;
6. Vermiculite: Like perlite, vermiculite is another mineral that has been superheated until it has expanded into light pebbles;

7. Sand: It is cheap and easily available. However, it is heavy and does not drain well, and it must be sterilised before reuse;
8. Gravel: Gravel is inexpensive, easy to clean, drains well and won't become water logged. It should be washed before use;
9. Brick shards: Broken up brick has been used in the place of gravel; and
10. Polystyrene: Very light weight, cheap, readily available and drain well (only non-biodegradable one should be used) (Anon., 2007a).

NUTRIENT SOLUTIONS

Plant nutrients are dissolved in water used in hydroponics and they are mostly in ionic form. Primary among the dissolved cations are Ca^{2+}, Mg^{2+} and K^{+}; the major nutrient anions in nutrient solutions are NO_3^-, SO_4^{2-} and $P_2O_4^-$ (Hydroponics Gardening Information, 2007). Commonly used chemicals for the macronutrients include potassium nitrate, calcium nitrate, potassium phosphate and magnesium sulphate. Various micronutrients added into hydroponics solutions include Fe, Mn, Cu, Zn, B, Cl, and Ni. Chelating agents are sometimes added to keep Fe soluble (Hydroponics Gardening Information, 2007). Plant might change the composition of the nutrient solutions upon contact by depleting specific nutrients more rapidly than others, removing water from the solution and altering the pH by excretion of either acidity or alkalinity. Care is required not to allow salt concentrations to become too high, nutrients to become too depleted, or pH to wander far from the desired level (Hydroponics Gardening Information, 2007; Fresh From The Garden, 2007).

COMPARISON OF HYDROPONICS AND CONVENTIONAL PRODUCTION SYSTEMS

Melgarejo *et al*. (2008) showed that hydroponics culture of fig (*Ficus carica* L.) resulted in higher profitability when compared to conventional farming. They obtained an 18-fold increase in fig fruit yield compared to traditional farming. In addition, they observed a 90% reduction in water use by applying hydroponics culture. Correa *et al*. (2008) reported a higher tuber yield in potato grown in hydroponics when compared to conventional system. They attributed the higher tuber yield to uninterrupted and optimal nutrient and water supply in hydroponics culture. In addition to the higher nutrient availability in hydroponics systems, it is also possible to monitor and control solution pH and electrical conductivity (EC).

Yields with hydroponics have averaged around 20 to 25% higher than in conventional cultivation (Parera, 2009). Hydroponics and greenhouse yields are commonly five times the field yield for a two crop per year field harvest and 10 times the field yield for a one crop per year field harvest (Anon., 2009b; Willis, 2009). In addition, since hydroponics plants have access to unlimited nutrition and water, they can grow up to 10 times faster and healthier than soil grown ones (FutureGarden, 2009). The growth rate of tomatoes in hydroponics culture is 30-50% faster than a soil grown plant, under the same conditions and the yield is also higher (Anon., 2009c)

The cultivation of greenhouse crops in closed hydroponics systems can substantially reduce the pollution of water resources by nitrates and phosphates in fertigation effluents, while contributing to an appreciable reduction in water and fertiliser consumption (Savvas *et al*., 2008). The absence of soil or soil-like medium in the hydroponics system removes the possibility of most pathogens and other damaging organisms (Correa *et al*., 2008). The technique also avoids the necessity of frequent crop rotation typically needed for field grown crops, as is typically needed to avoid build-up of soil-borne pathogens and pests.

Hydroponics culture is possibly the most intensive method of crop production in today's agricultural industry (Jensen, 2008). It is highly productive, conservative of water and land, and protective of the environment (Jensen, 2008). According to Correa *et al*. (2008), the absence of soil or soil-like medium in the hydroponics system removes the possibility of most pathogens and other damaging organisms. The technique is also used to avoid the necessity of frequent crop rotation typically needed for field grown crops, as is typically needed to avoid build-up of soil-borne pathogens and pests. Hydroponics growing systems have been developed to get higher yield and quality, to preserve water and land, to save labour and to protect the environment (Inden and Torres, 2004).

HYDROPONICS VEGETABLE PRODUCTION

Modern hydroponics techniques were used in China as early as 1970s to grow rice and vegetable seedlings (Xing and Ming, 1999). They observed that hydroponics-grown vegetables yields were 135% that of vegetables grown in the open field. Growing greenhouse vegetables is one of the most exacting and intense forms of all agricultural enterprises. In combination with greenhouses, hydroponics is becoming increasingly popular, especially in USA, Canada, Western Europe, and Japan (Jensen, 1999). It is high technology and capital intensive. It is highly productive, conserves water and land and protects the environment. For production of leafy vegetables and herbs, deep flow hydroponics is commonly used. For growing of row crops such as tomato, cucumber and pepper, the two most popular artificial growing media used are rockwool and perlite (Jensen, 1999).

Greenhouse food production often termed controlled environment agriculture (CEA) usually accompanies hydroponics (Jensen, 1999). Since regulating the aerial and root environment is a major concern in such agricultural systems, production takes place inside enclosures designed to control air and root temperatures, light, water, plant nutrition and adverse climate (Jensen, 1999). In rapidly changing world of hydroponics technology, yields higher than never realised before are possible. Consistent efforts have been made to develop simple, labour- and cost-efficient hydroponics systems (Schnitzler *et al*., 2004). Hydroponics growing systems have been developed to get higher yield and quality, to preserve water and land, to save labour and to protect the environment through reduced use of pesticides. Important advantages of hydroponics culture, especially the closed systems, are the excess nutrient solution is recovered, management and reduction of waste material, less pollution of ground water and surface water, a more efficient use of water and fertilisers, the buffer capacity for making mistakes and lower costs (Inden and Torres, 2004). Hydroponics culture allows direct control of the nutrient solutions, making it possible to modify composition and concentration to achieve predictable results in relation to dry matter, nitrate content, acceptable yields, shorter growing cycles, improved uniformity, automation of cultural techniques, high level of hygiene, and other organoleptic and structural features of vegetable produce (Frezza *et al*., 2005).

Lettuce is the fourth, most important vegetable crop grown hydroponically in the greenhouse, and is preceded by tomato, cucumber and pepper (Resh, 2007). Hydroponically grown vegetables are clean and free of soil. Lettuce, spinach and watercress (*Rorippa nasturtium-aquaticum* L.) can be grown in water culture systems such NFT, without the plants suffering from oxygen deficits, which normally occurs in long-term crops like tomato, cucumber and pepper (Resh, 2007). The specific formulation used is dependent upon temperature and sunlight. Lettuce will do well when provided with Ca (180-220 mg/L), P (50 mg/L), Mg (40–50 mg/L), K (210 mg/L), ammonium-N (15 mg/L), nitrate-N (165 mg/L), Fe (3–5 mg/L), Mn (0.5 mg/L), Cu (0.1 mg/L), Zn (0.1 mg/L), B (0.5 mg/L), Mo (0.05 mg/L). The optimum pH for lettuce is between 5.5 and 5.8 and electrical conductivity (EC) between 1.5 and 2.0 mS. The management of the nutrient solution is key to successful hydroponics growing. The availability of elements to the plants is dependent upon correct pH and the concentration and ratios of these nutrients in the solution. Some of the micronutrients such as Fe, Zn and Mn can be stabilised through the use of chelate forms (Resh, 2007).

According to Maruo *et al*. (2001), spinach grown in low concentration nutrient solution under NFT were found to have a slight retardation of growth, but there was no significant differences in marketable weight at harvest as compared to conventional hydroponics nutrient solution (590 mg/L $Ca(NO_3)_2.4H_2O$; 1,238 mg/L KNO_3; 153 mg/L $NH_4H_2PO_4$; and 493 mg/L $MgSO_4.7H_2O$. The low concentration nutrient solution reduced nitrate content and increased ascorbic acid content in the edible part of spinach plants. The use of low concentration nutrient solution makes it possible to control the amount of nutrients absorbed by the plants without disturbing plant growth or reducing yield.

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HYDROPONICS FRUIT PRODUCTION

Growing fruits all year round is no longer a dream with hydroponics gardening (Pocketgrow, 2013). However, not all fruits are suitable for hydroponics growing. One aspect of plant culture that is wise to keep in mind is to pay attention to the growing conditions a particular plant needs to survive and thrive (Agnock, 2013). Poor choices for hydroponics-style gardening are succulents, because they thrive in dry conditions (Agnock, 2013). Water loving fruit plants like water melons, cantaloupes, strawberries, raspberries, blue berries, grapes, etc. are good choice for hydroponics growing (Agnock, 2013, Crawford, 2013; Pocketgrow, 2013). There are some fruit trees that can be grown in hydroponics like bananas, lemon, orange, mandarins, avocados etc. (Agnock, 2013; Anon., 2013; Science in Hydroponics, 2013).

HYDROPONICS CUT FLOWER PRODUCTION

According to Evans (2008), hydroponics cut flower production is in vogue. Hydroponics culture is preferred where soil is poor or non-existent. Furthermore, soil-borne plant diseases may be eradicated more easily in hydroponics systems, and chemical run-off is more readily controlled. Hydroponics, or soilless culture, has become the principal method of growing vegetables and ornamental plants throughout the world (Resh, 2007). The use of hydroponics technology can be a viable alternative to methyl bromide soil fumigation for greenhouse grown tomato, strawberry, cucumber, pepper, eggplant, and some flowers (Anon., 2008b).

According to Gourly (2008) better quality flowers are being produced in a medium of gravel, cinders, or a similar inert material than in soil. In some cases, the yields are also relatively higher. For instance, 35 rose cut flowers are being produced per plant in gravel hydroponics culture while 20 cut flowers is the usual number produced in soil culture. Sweet peas average about 50% more in gravel than in soil culture. Carnations produce no more cut flowers in gravel, but the blooms bring a premium on the market because of their quality. The same may be said of snapdragons, calendulas, stocks, lilies, and daffodils.

In the 1990s, the government of the Netherlands began encouraging a reduction in the amount of chemical emissions into the environment so more and more producers switched to closed hydroponics systems (Armstrong, 2002). Hydroponics production of tulip bulbs increased from virtually nil in 1997 to over 40% in 2001 and the expectation is that it would rise to 90% by 2006 (Armstrong, 2002). According to Armstrong (2002), the majority of hyacinths are produced in soil but nowadays, most Dutch growers have perfected the hydroponics production systems.

In the Netherlands, approximately 30-35% of the tulips are grown hydroponically (The Flower Expert, 2008). Tulips are a good example of a flower bulb crop that can be adapted to hydroponics culture (The Flower Expert, 2008). High quality cut flowers of oriental hybrid lily were obtained in solid medium hydroponics system when compared to mist culture system (Ryota *et al*., 2002). They observed that broken chaff substrate, which had high water absorption and water holding capacity induced higher quality lily cut flowers as compared with chaff, hydro-ball or carbonised chaff substrate. Hsu *et al.* (2008) grew *Oncidium* orchids in rockwool, sphagnum peat moss and mixed medium containing crushed stone, bark and charcoal. They found that pseudobulbs mass, root activity, cut flower quality (flower length, floret number), and number of shoots were higher in rockwool compared to other media. Yamasaki *et al*. (2008) found an improved water circulation and rooting in tulips grown using NFT hydroponics system.

CONCLUSSION

Today, hydroponics culture is being used to successfully grow vegetables, flowers, herbs, and fruits in many countries in the world. Hydroponics systems are used to produce horticultural crops where field-grown vegetables and ornamentals are unavailable for most of the year. Hydroponics has improved the economic well-being of many communities throughout the world. Agriculture in most developing countries is characterised by low yields due to drought, disease, pest, and weed infestation. The seasonal production of crops also contributes to low production. The practice of hydroponics farming would help in solving this problem since the risks of soil-borne diseases and pests in crops is eliminated considerably. Hydroponics also enables off-season production since it can be practised in a greenhouse, so production is possible throughout the year, and it is one of the main answers to the problem of insufficient suitable land for arable farming. Moreover, the use of circulating hydroponics systems can help address the problem of drought and insufficient irrigation water availability. Hydroponics culture is possibly the most intensive method of crop production in today's agricultural industry. It is highly productive, conservative of water and land, and protective of the environment. The hydroponics systems are expected to become even more productive and will be able to feed people around the world in a more efficient manner.

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