HYDROPONICS: KEY TO SUSTAIN AGRICULTURE IN WATER STRESSED AND URBAN ENVIRONMENT

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Agriculture forms the largest sector of national economy of Pakistan. It is strongly linked with food security, poverty alleviation, rural development as a means to achieve bigger goals including employment led economic growth through its linkages and multiplier effects. The agriculture sector, however, faces some crucial and critical challenges. Pakistan population during the last three decades has increased from 65 million to 162 million at present, and is expected to increase to 234 million by 2025, reaching 357 million by 2050. This buildup of massive population momentum will place immense pressure on agriculture resource base calling for substantial increase in food production.

Worldwide arable land is already less than 0.2 ha per capita at present, and is expected to further shrink to 0.15 in 2050. Situation is extremely alarming in Pakistan, where per capita land availability has progressively declined to 0.15 ha at present, shrinking further to 0.06 ha by 2050. Similarly, the per capita water availability has dropped from 5600 cu meters to 1200 cu meters, which could slip further to the water-deficient level i.e. below 1000 cu meters per year by 2010 onwards. Therefore, the potential and the capability to meet growing demands for food in the form of technology adaptability need to be rationally embarked upon with a firm commitment and dedication. The greatest challenge lying ahead is to increase food and fiber production while maintaining the ecosystem stability and rehabilitation of the environment. The problems being arising out of this scenario are to be overcome in such a manner, so that; everyone can be adequately and nutritiously fed without over-exploiting the natural resources. Hydroponics is one such valuable means of growing fresh vegetables and fruits including flowers not only in countries having shrinking land and water resources but also those having large populations. Hydroponics can simply be defined, as the growing of plants in a water and fertilizer solution containing necessary nutrients for plant growth. It can also be defined as soilless agriculture or growing plants in soilless medium.

Hydroponics as a word was coined in 1930 by W. E. Gericke of University of California, meaning water and labour in other words i.e. water working or growing plants in a nutrient solution with out soil.

Hydroponics is a very young science. It has been used on a commercial basis for only 40 years. However, even in this relatively short period of time, it has been adapted to many situations, from outdoor field culture and indoor greenhouse culture to grow fresh vegetables. It is a space age science, but at the same time can be used in developing countries of the third world to provide intensive food production in a limited area. It's only restraints are sources of fresh water and nutrients. In areas, where even freshwater may not be available, hydroponics can be used through desalination of seawater. It has the potential application in providing food in areas having vast regions of non-arable land, such as deserts and dry coastal belts.

The science of hydroponics is characterized by the fact that soil is not needed for plant growth but the elements, minerals and nutrients that soil contains are definitely required. Soil is simply the holder of the nutrients, a place where the plant roots traditionally live and a base support for the plant structure. By eliminating the soil, it also eliminates soil borne diseases and weeds and gains precise control over the plant's nutritional requirements. In a hydroponic solution, one provides the exact nutrients the plant needs in precisely the correct ratios so that they can develop stress-free, mature faster and, at harvest, are the best in quality acceptable both to customer and consumers liking. With the

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development of plastics, hydroponics took another leap forward and is now a widely accepted method of producing certain specialty crops such as tomatoes, lettuce, cucumbers, bell peppers, herbs, foliage plants, and flowers. Most of the tulips and roses exported from Holland are also grown hydroponically. The controlled environment agriculture and hydroponics seems to be the answer to many of the difficulties associated with the production of outdoor specialty crops in the wake of continued soil degradation, loss of fertility, indiscriminate chemical inputs use, and above all continued depletion of water resources.

In traditional agriculture fields and gardens, plant roots are in the soil. They support the plant and search for food and water. In hydroponics, a growing medium in place of soil is used to help support the plant and to absorb the nutrient solution. The roots of a hydroponic plant do not work as hard as those of a plant grown in soil because their needs are readily met by the nutrient solution provided. Ideal mediums are chemically inert, porous, clean and able to drain freely.

Keeping in view, the water stresses being frequently encountered within the country, the soilless agriculture does not seem to be the wave of the future. It's going to be here specially for high-value crops such as fruits, vegetables and flowers as they consume 10-30 times less water than field grown produce for the same area and are also devoid of the hazards associated with indiscriminate use of synthetic fertilizer, insecticide and pesticide sprays. Besides, the green house hydroponic crops can be grown all the year around irrespective of seasons and make crops freshly available in the local markets and fetch better prices because of being better in appearance as well as quality and also being devoid of chemical influences. With hydroponic technology and a controlled green house environment, one gets the latitude and ability to grow premium quality produce using a minimum of space; water and fertilizer. Although hydroponic crops are grown on more than 40,000 acres all over the world with U.S. accounting for more than 1000 acres alone, yet technology needs a better momentum for its harness and adoption.

Hydroponics is an intensive form of agriculture that may fulfill the consumer's demand for premium produce and provide the grower with a profitable business. The commercial hydroponics in Europe and United States has dramatically risen through productivity as profitable ventures during past decade so much so, the growers are harvesting 35-40 lbs of tomatoes per plant as compared to 20 lbs few years back, and an intensive volume could be grown in small space i.e. 4-5 thousand pounds of tomatoes every week in an area of 12000 ft^2.

MATERIALS FOR HYDROPONICS

Since the beginning of hydroponics, many materials have been used as hydroponic growing mediums, some of which include vermiculite, saw dust, sand and peat moss. More recently, rockwool, perlite and expanded clay pebbles are available as excellent choices for hydroponics.

a. Perlite

Perlite is derived from volcanic rock which has been heated to extremely high temperatures. It explodes like popcorn, resulting in the porous white medium which can be used in hydroponics. In addition to uses in hydroponics, perlite is also used in many commercial potting soil mixes and in non-horticultural areas including construction and as a packing material.

Perlite can be used loose in pots or bagged in thin plastics sleeves (referred to grow bags) as the plants are grown right in these bags. Plants in perlite grow bags are usually set up on a drip feed system and each standard bag holds 3 or 4 long and tall plants.

b. Rockwool

Rockwool is derived from basalt rock. It too is heated to high temperatures and is then spun into fibers resembling insulation. These fibers are further spun into cubes and slabs for hydroponic production. The cubes are commonly used for plant propagation and the slabs are used similarly to perlite grow bags. A plant is set onto the rockwool slab and grown there. The plant roots grow down into the slab. Rockwool slabs usually hold 3 or 4 large plants.

c. Expanded Clay Pebbles

Many hobby hydroponic gardeners use expanded clay pebbles for their growing medium because they have a neutral pH and excellent capillary action. For commercial ventures, expanded clay pebbles are generally considered too costly.

Characteristics and Attributes of Hydroponics

- The controlled environment growth leads to premium quality produce.
- High grade nutrients and precise control of the nutrient feed rations at the time of ripening.
- No sterilization of growing media required and plant nutrition is easily and completely controlled within the nutrient tanks.
- The lack of herbicides and pesticides influences on green house hydroponic crops (have no or very little risk of weeds, parasites, insects and pests etc.) is more acceptable to consumers.
- No soil borne diseases including weeds in hydroponic produces.
- Uses only up to $1/10^{th}$ – $1/30^{th}$ of the water which otherwise would have been used to grow equivalent amounts of field produce.
- System as a whole, allows for uniform water availability to plants.
- Hydroponics uses less fertilizer than is often used to grow equivalent amounts of field produce.
- Extended growing season i.e. crops can be grown all the year around so no regulated growing of crops needed or fallowing needed.
- Intensive production in a small space i.e. more plants per sq. foot and much greater yields at harvesting.
- No loss of fertility so no crop rotation as in soil borne crops.
- Superior taste, quality, appearance, uniformity, and extended shelf life of hydroponic vegetables.
- Closer plant spacing is possible and moveable plant channels allow greater production from equal areas for some crops.
- Certain vegetables i.e. Root zone heating, known to benefit tomatoes and cucumbers, is feasible and practical.
- Use of biological controls including beneficial insects and safe methods of insect control are possible and practical in a controlled environment system.

Growing methods in Hydroponics

In commercial hydroponic production, the two primary growing methods are drip (also known as substrate) and NFT (Nutrient Film Technique). There are a number of variations of these methods and also several others including the float system, ebb and flow system, aquaponics, aeroponics and passive hydroponics have also been practical. The biggest difference between the drip and NFT systems is the use of a growing medium. In a drip system, the plant roots are in a growing medium such as perlite or rockwool and the nutrient solution is dripped onto the medium to keep it moist. In an NFT system, the plant roots are in a channel where a thin film of nutrient solution passes, keeping them moist but not water logged.

I. Drip (Substrate) system

The drip system is often used in commercial hydroponic facilities that grow long term crops like tomatoes, cucumbers and peppers. In this system, the nutrient solution is delivered to the plants through drip emitters on a timed basis. The emitters are usually scheduled to run for approximately 10 minutes of every hour depending on the stage of development of the plant and the amount of available light. The drip cycle flushes the growing medium, providing the plants with fresh nutrients, water and oxygen.

In a commercial drip system, the plant roots are most commonly grown in a medium of perlite or rockwool. The biggest variables in a drip system are in the growing medium and the container that holds that medium. Perlite is often bagged in thin, plastic sleeves. Holes are cut in the bag and plants usually, 3-4, are set in with the roots growing down into the perlite. Recently, a bucket system has been developed to contain perlite for drip systems. Each bucket holds lose perlite and one or two plants. In either of these methods, a slot or hole is cut in the container to allow excess nutrient solution to run out. A drain line below the bag or bucket collects the excess.

Another method of a drip system that is becoming popular for lettuce and herb production is the perlite tray, usually about 24 inches wide and 10-14 feet long. An aluminum tray, coated with a non-toxic material, is filled with perlite and set on a gentle slope of 1-inch to every 10 feet. The nutrient solution is continuously dripped in, at the higher end of the tray and allows trickling through the perlite to the other end. Essentially, this system is a combination of drip and NFT techniques.

In most drip systems, injectors are used to add nutrient concentrates to water when the feed cycle starts. In this case, there is no need for a large nutrient reservoir tank or the periodic dumping of used nutrient.

II. NFT (Nutrient Film Technique) system

With the NFT technique, the plants are grown in channels (also called gullies) through which the nutrient solution is pumped. The plant roots are kept moist by the thin film of nutrient solution as it passes by. Ideally, the bottom of the roots are exposed to the nutrient solution while the top are kept moist but not water logged.

Most NFT channels are fed continuously at a rate of approximately 1 liter per minute. Since the plant roots are not in a growing medium, it is crucial that they are kept moist at all times. In most NFT systems, the nutrient solutions mixed in a primary reservoir, are cycled through the channels and back to the reservoir. With the development of on-demand dosing equipment, a nutrient reservoir can automatically be adjusted, and with proper aeration and pH adjustment can effortlessly be kept fresh for weeks at a time.

NFT is ideal for lettuce, leafy crops and herbs, all of which are short terms crops. Larger NFT channels are used for long term crops such as tomatoes and cucumbers in many locations around the world. One great benefit of NFT, especially for leafy crops, is that the crops are clean and no washing is necessary. Growers, grocers and consumers all appreciate this type of crop even if to be marketed as such.

NFT channels are usually set up on waist-high stands that slope slightly to allow the nutrient solution to drain to one end. Although round pipes have been used in NFT production, most growers have found that flat bottomed channels or gullies provide greater surface area for root development and oxygen uptake, resulting in better and faster plant growth.

III. Float system

Float systems have the advantage of the economy and the surface for the nutrient solution. Most float systems are long, rectangular reservoirs built out of cement or wood and lined with a durable polyliner. Holes are cut in a foam board which floats on the surface of the water and plants in net pots are set in the holes. The plant roots dangle in heavily aerated nutrient solution.

In areas where raw materials are limited and manufactured hydroponic systems are not available, the float system can be an economical means of hydroponic crop production.

IV. Ebb and Flow system

The Ebb and Flow (also known as flood and drain) method of hydroponics simply floods a growing area for 5 or 10 minutes and then the nutrient solution drains away. The nutrient solution is stored in a reservoir that can be located under the grow table. Ebb and Flow is common in hobby systems but not often found in commercial production. In an Ebb and Flow system, the plant roots are usually grown in a medium of perlite, rockwool or expanded clay pebbles.

V. Aquaponics system (Integrated system approach)

In hydroponics, a specific nutrient formula is mixed in solution and is fed to the plants. In aquaponics, aquaculture (fish farming) is combined with hydroponic production. The nutrient-rich waste water from the fish tank is pumped through plant beds. Although not as precise as a hydroponic fertilizer mix, the effluent from a fish tank is high in nitrogen and many other elements and most plants do quite well in aquaponics, through this integrated system approach. The key to aquaponics is the establishment of a healthy bacteria population. Beneficial bacteria that naturally occur in the soil, air and water convert ammonia (the primary form of fish waste) to nitrite and then to nitrate, which the plants readily uptake. In consuming the nitrate and other nutrients in an aquaponic system, the plants help to purify the water. Although the combination of hydroponics and aquaculture is quite new, the interest in this technology is booming. Aquaculturists who normally have to buy expensive water purification equipment to purify the water see aquaponics as a great way to clean the water and end up with another, very marketable crop. Hydroponic growers see the value in a natural source of nutrients, already in solution. The water from a fish tank can be pumped through any hydroponic grow bed in place of a hydroponic fertilizer solution. The commercial aquaponic production system is designed to show great promise as it may include the float, NFT and ebb and flow, methods.

VI. Aeroponics

Aeroponics is the method of growing where the plant roots are constantly misted with a nutrient solution. Designs include frame with boards on each side, plant plugs set in each side and a mister between the boards spraying the roots. A round, large diameter PVC pipe set vertically with plant plugs all the way around and a mister mounted inside is another way to set up an aeroponic system. Although aeroponics is a unique way of growing, it is not a common means of commercial production.

VII. Passive hydroponics

Passive hydroponic systems are sometimes used by hobbyists. A passive system does not use pumps or timers to flood the root zone. The roots usually dangle into the nutrient solution and draw what they need. A passive system is generally slower growing and not as productive as the other methods discussed, above.

The growing awareness of environment and ecosystem among the people make hydroponics technology most ideal to protect the degradation of natural resources. This technology requires no soil, less water for culture, less area, free of disease and pest and highest food production. It plays vital role in developing areas with water scarcity, small arable land area, environmental concerns in controlling pollution and quality of groundwater and problem of food security. It can effectively be exploited as a tool in backyard farming and house top agriculture practices. In urban atmosphere with limitations of soil accessibility, hydroponics could serve as best means to earn livelihood through continued growth of vegetable and even flowers on a limited scale under given local environment.

REFERENCES

Arteca, R. N and J. M. Arteca. 2000. A novel method for growing *Arabidopsis thaliana* plants hydroponically. Physiol. Plant, 108: 188–193.

Benton, J. J. 2004. Hydroponics. A practical guide for the soilless grower. 2nd Edition, CRC Press. pp. 35-150.

Board on Agriculture. 1991. Sustainable Agriculture Research and Education in the Field: A Proceedings. National Research Council. National Academy Press. Washington D.C., USA.

Bugbee, B. 2004. Nutrient management in recirculating hydroponic culture. Acta Hort., 648 : 99-112.

Charles, N. B. 1979. Aquaculture and Hydroponics, Dept. of Agriculture, Science and Education Administration, Technical Information Systems. Washington, D.C., USA.

Douglas, J. S.1975. Hydroponics: The Bengal system with notes on other methods of soilless cultivation. 5th ed. Oxford University Press. USA. pp. 80-190.

Gilbert, H. 1994. Hydroponics-Nutrient Film Technique. National Agricultural Library, Beltsville, Md. USA.

Harris, A. 1974. Hydroponics, growing without soil: easy-to-follow instructions for the flat dweller, modern gardener and commercial grower. Newton Abbot : David & Charles, publishers.

Lennard, W. A. and B.V. Leonard. 2006. A comparison of three different hydroponic sub-systems (gravel bed, floating and nutrient film technique) in an Aquaponic test system. Aquacult. Int., 14: 539–550.

Nhut, D. T., N. H.Nguyen and D. T. Thuy. 2006. A novel *in vitro* hydroponic culture system for potato (*Solanum tuberosum* L.) microtuber production. Sci. Horti., 110 :230-234.

Paulitz, T. C. 1997. Biological control of root pathogens in soilless and hydroponic systems. Hort. Sci., 32: 193–196.

Piekarczyk, D. J. 1995. Profitability of hydroponics for agribusiness and wholesale markets. Johnson and Wales University thesis, U.K.

Resh, H.M. 1993. Water culture. In: Howard, M.R. (ed.), Hydroponic Food Production. Woodbridge Press Publishing Company, pp. 110–199.

Resh, H. M. 2001. Hydroponic food production: a definitive guidebook of soilless food growing methods. 6th ed. Woodbridge Press Publishing Company, pp. 210–499.

Schwarza, D., R. Groscha, W. Grossb and S. Hoffmann-Hergartenc. 2005. Water quality assessment of different reservoir types in relation to nutrient solution use in hydroponics. Agric. Water Manage, 71:145–166.

Sutherland, S. K. 1999. Hydroponics for everyone: a practical guide to gardening in the 21st century. Hyland House Publishing. South Melbourne, Australia.