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Soilless cultivation in Lettuce: A Review

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ABSTRACT

Several studies have revealed that in the near future, the problem of feeding the increased population will skyrocket due to the rapidly rising population. Conventional methods of food production will not be sufficient for huge amounts of food requirement, as it has several constraints such as non-uniform distribution of mineral rich farmland and water resources, moreover continuous use of fertile farmland has also aided in reduced productivity. Although current food production is sufficient but still it is not wisely distributed as an urban area is still depend upon rural areas for their food demands, Soil less cultivation is one such way in which we can produce food in urban areas and by using resources wisely and efficiently. This review paper will discuss the potential of lettuce grown through different soil less media and some major varieties of lettuce. This paper will provide an overview of some important hydroponics systems their working and their suitability for lettuce production and will also discuss some characteristics of lettuce that is grown hydroponically focussing mainly on observable characteristics. Moreover, it will highlight the effects of different soilless media on growth of lettuce and will also provide a brief description on the effect of different combinations of coloured lights on growth of lettuce. As hydroponics is energy efficient it has sustainable goal of 'Responsible Consumption and Production' i.e., goal number twelfth, further as it gives higher production it also helps in meeting the requirement of second goal of sustainable development i.e., 'Zero Hunger'.

Key words: *Hydroponics, Lettuce, Soil less cultivation, Water management, Sustainable development goal.*

Introduction

Lettuce botanically known as *Lactuca sativa*, a member of Asteraceae (composite) family. A leafy annual originated from the Mediterranean region, now being cultivated commercially worldwide mainly for leaves to be consumed as salad. *L. sativa* is assumed to have evolved from wild lettuce (*L. serriola)* nearly 4,500 years ago in Egypt, into different cultivars having varying leaf size, colour, and growth form (Agius, 2017). As it is temperate originated some successfully developed cultivars are well adapted in tropical regions. Lettuce has been described as a weed Cinderella by "(Whitaker)" and is likened to "the queen of salads" by (Martin and "Ruberté, 1995). Leaves are either of ruffled, toothed, or smooth type. Similarly, growth forms also varied in different forms viz. loose-leaf cluster, densely packed leaves heads, or stem lettuce whose leaves possess edible stems (Agius, 2017). In some Eastern countries such as China and in Egypt, the stem instead of the leaves of lettuce was used for eating, cooked, raw, pickled, dry or sauce. Some fewer common uses of lettuce include a cigarette without nicotine from lettuce leaves, cooking oil extracted from the seeds of a lettuce, and a sedative made from the

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dried latex found in plant stems and other tissues. Lactucarium, the dried latex produced from a relative of wild lettuce, *Lactuca virosa* L., used to make sleeping pills (Ryder, 1986).

Lettuce (*Lactuca sativa* L.) is a widely grown and popular leafy vegetable consumed around the world, its leaves can be easily found in sandwiches and salad mixtures (Mou, 2004). The largest producer of lettuce in the world is China, where instead of leaves, stems are consumed either raw, cooked, pickled, dried and sauce form (Mou, 2004). Lettuce is the third most consumed vegetable in America (USDA, 2015). So, lettuce can make a significant contribution to the nutritional content of the diet (Kenny and O'Beirne, 2009). Since lettuce is usually eaten raw, it is more nutritious compared to other cooked vegetables or processed foods, such as potatoes. In addition, the consumption of mixed salads belongs to the first leaf (cotyledon), or seedling (small leaf) obtained popular as a culinary trend (Xiao *et al*., 2012).

Lettuce is considered a poor source of nutrients while it is rich in calcium, iron, and vitamin A(Niederwieser, 2001; Maboko, 2007). It has low nutritional value; the nutritional composition of lettuce, depending on environmental conditions and type, may be equivalent to other "nutritious" vegetables (Kim *et al.*, 2016 b). Salad contains a number of minerals important to human health such as iron (Fe), zinc (Zn), calcium (Ca), phosphorus (P), magnesium (Mg), manganese (Mn) and potassium (K), among others health-promoting bioactive compounds (Kim *et al*., 2016 a; b). Epidemiological studies have reported a correlation between consuming fresh vegetables and reducing the risk of chronic diseases. Lettuce is low in fat but contains polyunsaturated fatty acids (PUFAs), which are important for health. PUFA Omega-6, Linoleic acid (LA) and α linolenic acid (ALA), an omega-3 PUFA, are essential fatty acids that must be obtained from food Kaur *et al*., (2014). Lettuce also provides poorly digested and low-calorie carbohydrates such as sugar alcohols. It also contains dietary fibre(USDA, 2015). Investigations have demonstrated the potential therapeutic effects of *Lactuca sativa* through various studies.

Generally, the lettuce can grow to a leaf size of about 15 cm long, which can either be loose or tightly clustered. The lettuce can be harvested before it begins to flower. A lettuce plant that has been allowed to flower can grow up to 1 m tall. The flowers are composite yellow and have one seeded fruit called an achene with a white beak (Agius, 2017).

Typeof lettuce

A great diversity on basis of shape, size and colour are available in lettuce cultivars, and the lettuce are classified into types mainly based on their leaf shape, size, stem type, head formation and texture (Mou, 2008). Among these, six recognized types of lettuce are Leaf, romaine, head (crisphead, butterhead), stem, latin and oil seed.

Hydroponics

Hydroponics term consist of two words 'Hydro' and 'Ponics' which means water and labour respectively. The term was coined by Professor William Gericke in the early 1930's (Resh, 1993) states that "Hydroponics is a valuable method of growing clean vegetables not only for countries with the smallest arable land, but also for small countries with large numbers of citizens". It can also be especially useful in smaller countries where tourism is a major industry, where hotels and tourist facilities have taken up most of the country's arable land, forcing conventional agriculture to fade away (Sardare and Mamta, 2013). Hydroponics can be done on the remaining uncultivated land to provide enough clean vegetables for locals as well as tourists. Greenhouse soilless crop production is the most environmentally friendly farming technique as it can reduce the use of chemical pesticides and aids in efficient use of natural resources and is a less consumptive farming system for the earth. Furthermore, low quantity but regular fertilizing is the most advanced farming technique, as it can reduce management work, improve yield, and achieve stable yield.

The accumulation of pests in the soil has always been a dilemma in protected areas. Production is maintained by the practice of soil sterilization. Sterilize with steam in some cases where it is not economically viable and the use of methyl bromide, is Common soil disinfectant, banned in many states and phased out in 2005 in countries that are industrialized according to the Montreal Protocol. One of the alternatives is no land culture (Van Os, 2000).

Hydroponics systems deliver water and nutrients to the growing plant at a consistently high relative moisture potential (Wheeler, 2010; Ciju, 2012). These systems help address climate change challenges and manage production systems for the efficient use of natural resources and mitigation of malnutrition

(Butler *et al.*, 2006). Aeroponics is another technique somewhat like hydroponics, with the only difference being that aeroponics use microscopic droplets of nutrient solution (fog or aerosol) to grow plants (Ellis *et al*.,1974). In India, hydroponics was introduced in 1946 by British scientist W. J. Shalto Douglas, who established a laboratory in the Kalimpong area of West Bengal. He also drafted a book on hydroponics called Hydroponics Bengal System. In the 1960s and 1970s, commercial hydroponics farms were established in Abu Dhabi, Arizona, Belgium, California, Denmark, Germany, the Netherlands, Iran, Italy, Japan, the Russian Federation, and other countries. The 1980s saw the creation of many automated and computerized hydroponic farms around the world. Home hydroponics kits became popular in the 1990's (Sardare and Mamta, 2013).

In addition, hydroponics offers more opportunities to bring fresh produce to market due to higher average nutritional quality and higher consumer acceptance (Mehra *et al*., 2017). In addition, growers report that with hydroponics, some of the negative effects of conventional farming are avoided, including high and inefficient water use, large soil requirements, and nutrient-dense soil. high, pesticides and soil degradation accompanied by erosion(Treftz and Omaye, 2016; Horrigan *et al*., 2002). Consumers around the world are increasingly interested in more environmentally friendly clean vegetables due to the inverse relationship between vegetable consumption and the risk of many chronic and degenerative diseases such as cancer, cardiovascular and neurological (Kris *et al*., 2002). These beneficial compounds can be influenced by a number of key factors, including environmental conditions (light, temperature, humidity, atmospheric CO_2). Unlike conventional agricultural systems, hydroponics is based on the manipulation of nutrients, which, according to different authors, allows the production of products with a high accumulation of certain beneficial nutrients (Sgherri *et al*., 2010; Buchanan and Omaye, 2013).

Types of hydroponics system for lettuce

The hydroponics setup you will use for the growth of lettuce will solely depend on your growing needs. For large scale commercial production of lettuce, the most common hydroponics systems used are the Dutch Bucket System, the Nutrient Film Technique, and the Deep-Water Culture.

Ebb and Flow

Also called the flood and drain system. In this system, you flood the root zone of the plants with nutrient solution and drain it back into the reservoir (Biosci *et al*., 2021). This hydroponics system works by temporarily flooding the growth tray. The nutrient solution from the reservoir surrounds the roots before draining again. This task is usually automated by a water pump on a timer (Solanki *et al*., 2017). It is quite convenient to grow plants in this system but still has a drawback that in this system root rot and mould growth is quite common (Nielsen *et al*., 2006).

DWC/ Floating raft system

Deep water culture consists of a nutrient solution in bulk. This solution is found inside built reservoirs and ponds. For DWC, you need a pump to circulate the water and an air pump to aerate the pond. The large volume of water helps to ensure safety against rapid changes in nutrients and temperature (Biosci *et al*., 2021). Hydroponic The bucket system is a classic example of such a system. Plants are placed in net pots and roots suspended in nutrient solution where they grow quickly in bulk. Obligatory supervision of oxygen and nutrient concentrations, salinity, and pH (Domingues *et al*., 2012) in the form of algae and moulds can grow quickly in tanks. This system uses floating polystyrene rafts or sheets with drilled holes. The nutrient solution is contained in a nutrient-rich lake. This system is ideal for short-day crops such as lettuce (Biosci *et al*., 2021).

Nutrient Film Techniques (NFT)

Your plants in an NFT system will grow in shallow trenches with constant nutrient circulation to the root zone. The inclination of the channel allows drainage towards the reservoir (Biosci *et al*., 2021). In this system, water or a nutrient solution circulates throughout the entire system; and enters the growth tray via a water pump without a time control (Domingues *et al*., 2012). This system is also quite popular among home hydroponic growers. Mainly due to its rather simplistic design, the N.F.T. The system is best and most often used for growing small, fast-growing plants such as various types of lettuce. Along with growing lettuce, some commercial growers also use NFTs to grow various types of herbs and vegetables (Solanki *et al*., 2017).

Vertical System

This system is designed to produce vertical crops irrigated from above. Gardeners can increase plant populations if space is limited. The system includes stand-up bags or stacked gourds (Biosci *et al*., 2021). You can make efficient use of growing space and create aesthetically pleasing living room walls. This system is ideal for growing strawberries due to its shallow root system. TriCycle plans to grow strawberries on vertical walls.

Specific Considerations

Growing media

There are three main types of soilless cultures: buffer substrates (eg: substrate), inert substrates (e.g., rockwool) and no substrates (e.g., NFT). Although NFT is used for commercial purposes, it is reported to have certain risks, e.g., spread of disease, and lack of buffering for mismanagement. On the other hand, Media cultivation is becoming important every year around the world. Substrates used differently from country to country, for example rock wool is popular in Northwest Europe, while locally quarried perlite and pumice are widely used in Southern Europe (Van Os, 2000).

Choose the right media to grow your hydroponic lettuce crop. There are many types of media on the market, including rockwool, perlite, composted pine bark and coir. Other substrates that can be used as supports include river rock and expanded lightweight clay aggregate (LECA).

Vermiculite

It is a mica mineral that is heated at about 2000°F until it turns into gravel. It is considered an excellent medium for rooting. It is often used to grow seedlings along with other types of media such as coconut or peat moss. Produced in a variety of grades, the most common are 0-2mm, 2-4mm, and 4-8mm diameters (Dunn *et al*., 2021).Vermiculite is used as a component of the sowing medium and soil mixture to cover germinating seeds. Medium containing vermiculite should be mixed dry. The desired physical properties are compromised when wet mixing causes the particles to become flat (Handreck and Black, 2005). Perlite is mainly used to improve the drainage properties of the mixture, while vermiculite is used to increase the water holding capacity of the growing medium. It can hold 3 to 4 times more water than its own weight. Vermiculite can also contain positively charged nutrients such as potassium, magnesium and calcium (FAO, 2013).

Light Expanded Clay Aggregates (LECA)

LECA is a special type of clay that is granulated and fired in rotary kilns at very high temperatures. Firing burns the organic compounds in the clay, melting the outer surface of each pellet, and during sintering the pellets expand into a honeycomb shape. The resulting ceramic granules are light, porous and highly resistant to crushing (Boudaghpour and Nasir, 2008). Expanded clay granules are made by heating and expanding dry heavy clay to form round, porous balls. Commonly known as Lightweight Expanded Clay Aggregate (LECA), Growth Stone or Hydroton®. They are heavy enough to support the plant, yet light. Their spherical shape and porosity help maintain a good oxygen-water balance so that the roots do not dry out or overflow (Dunn *et al*., 2021).

Rockwool

Mineral wool (e.g., Rockwool) is a sterile, porous, non-degradable medium composed primarily of granite and/or limestone that is heated and melted, then rotated into fine threads and formed into blocks, sheets, cubes, slabs or flocking. It absorbs water well and has good drainage, so it is widely used as a starting medium for seeds, as a root medium for cuttings, and as a root medium for large biomass crops such as tomatoes (Dunn *et al*., 2021). This material is cube-shaped with pre-made holes for seed placement. Rockwool is made by blowing molten rock, creating fibres that are spun and pressed into sheets of inert mineral that are ideal for holding water and air. Most rock wool products require soaking in a prepared pH buffer to remove the natural alkalinity of the substrate (Agius, 2017).

Perlite

This medium is made of porous natural volcanic glass pebbles. It is made by expanding rock at high temperatures. Perlite is commonly used in potted plant mix to improve air and moisture holding. Perlite is essentially a type of volcanic rock, which has expanded when heated to about 980 °C. Perlite is known to be sterile with a pH of about 7.0 to 7.5, has a very low cation exchange capacity, and buffering capacity. Decay and deterioration are not experienced in perlite unless it is physically destroyed.

Water holding capacity is due to its irregular surface areas. Perlite is generally added to growing media to increase its aeration, and provide better drainage. Pearlite is an established substrate with many advantages: it is a natural material, inorganic, and therefore physically stable, does not decompose, is chemically inert at neutral pH, and is sterile. No pests, pathogens, no weed seeds. It is also clean, odorless, lightweight and easy to handle. Its benefits have been proven in several tests (Marsic and Jakse, 2010)

Coconut fibre

This growing medium is derived from the coconut industry. This medium is also commonly used in nursery plant production. Coconut husks are ground and compacted to be shipped and marketed. It does provide a great substrate for air and water exchange by the roots, but as with the composted pine bark, it too can bind N and increase production costs. It comes in pellet form, brick form, and other products that can be incorporated in a home hydroponic system (Agius, 2017). Coconut fiber pressed into pellet and brick form requires a soaking period to expand the media prior to use. Coco coir can be used as a peat alternative for growing a large variety of products. Nowadays coco coir has gained market acceptance and is not defined by consumers as the poor cousin of European peat. Coco coir nowadays is used for potting mixes and hydroponic production replacing rockwool, perlite and sawdust. Coconut powder is the most suitable among non-soil cultivation methods because it is inexpensive, requires less equipment, is easy to operate, and is available locally. With increasing environmental pressure on greenhouse growers to use sustainable or renewable resources, coconut fibre dust is rapidly being consumed as a modern sustainable substrate (Resh, 2013).

Zeolite

Zeolite is hydrated an aluminium-silicate mineral in which the Al and Si tetrahedra are joined by a common oxygen atom to form a three-dimensional frame structure. They are characterized by an ability to lose and gain water as well as exchange cations without major structural changes (Mumpton, 1999; Kithome *et al*., 1999). The structure of the generated zeolite adsorption and ion exchange properties, making them potentially useful in the field hydroponic crop production (Harland *et al*., 1999). More than 40 natural zeolites species, clinoptilolite appears to be the most abundant zeolite in soils and sediments. It has a relatively high ion exchange capacity with great preference cations like $NH4^+$ and K^+(Harland *et al*., 1999).

Light Requirements

The hours of light your lettuce will need will depend on the light you use and how close you keep the lights to your plant. Understand the optimal light requirements of your plant. Daily light integral or DLI measures the light. You calculate your DLI by measuring the photon flux density (photosynthetic). The DLI only indicates how much light plants need

Table 2. Effect of different growing media on leaf length of lettuce

Substrate	Leaf length(cm)	Reference
Cococoir/Cocopeat	30	Agius, 2017
Soil	15.75	Agius, 2017
Peat Soil Mix	21.50	Agius, 2017
Perlite peat mix	22.45	Agius, 2017
Cocopeat reused	27.11	Agius, 2017
Rockwool	27.74	Biosci *et al*., 2021
Sawdust	22.45	Biosci *et al*., 2021
Carbonized Rice Hull	23.33	Biosci *et al*., 2021

Table 1. Effect of different growing media on fresh and dry weight of lettuce

Substrate	Fresh Weight(g)	Dry Weight(g)	Reference
Cococoir/Cocopeat	294.2	18.5	Agius, 2017
Soil	108.8	13.1	Agius, 2017
Peat Soil Mix	170.6	15.8	Agius, 2017
Perlite peat mix	209.6	18	Agius, 2017
Cocopeat reused	204.7	18.4	Agius, 2017
Perlite	225	18	Agius, 2017
Rockwool	179.23	-	Biosci *et al*., 2021
Sawdust	155.85	-	Biosci *et al*., 2021
Carbonized Rice Hull	154.62	-	Biosci *et al*., 2021

Table 3. Effect of Different Colour light on Growth of Lettuce

Light	Ratio	Fresh Weight (g)	Dry weight (g)	Reference
RB	75:25	58	4	Li *et al*., 2021
RB	83:17	70.85	10.45	Mohamed *et al*., 2021
RB	91:9	78.45	12.28	Mohamed *et al*., 2021
RB	95:5	72.52	9.15	Mohamed *et al*., 2021
RB	100:0	64.82	6.95	Mohamed *et al*., 2021
RBG	60:20:20	30	3.25	Li *et al*., 2021
RBG	80:10:10	122		Matysiak *et al*., 2021
RBG	70:20:10	138		Matysiak *et al*., 2021
RBG	60:30:10	119		Matysiak *et al*., 2021
RBG	70:12:18	155		Matysiak *et al*., 2021
RBP	60:20:20	50	3.5	Li *et al*., 2021
RBF	60:20:20	50	3.25	Li *et al*., 2021

RB- Red: Blue, RBG- Red: Blue: Green, RBP- Red: Blue: Purple, RBF- Red: Blue: Infrared

at a particular wavelength. For lettuce, you do not have to worry about the optimum or perfect light cycle but enough lighting that will keep the plant healthy (Mohamed *et al*., 2021). There are various growth lights that can be used in the greenhouse. Common types are incandescent, fluorescent, and LED. These are some of the five most used fluorescent, high-intensity discharge, and LED lights. In general, lamps with the lowest initial cost of capital are often the most expensive and least effective in the long run.

Nutrient Requirements

The hydroponics lettuce needs nutrient solutions of high quality to thrive and survive. Hydroponics requires close monitoring of the system due to its limited nutrient buffering capacity and ability to make rapid changes (Singh and Singh, 2012). Of the many factors that lead to high yields of soilless crops, adequate nutrient supply is considered one of the most effective tools (Munsi, 1992).

Temperature requirements

In hydroponics, increasing the temperature can stimulate water and nutrient absorption, thereby accelerating metabolic processes and thus promoting shoot growth (Dong *et al*., 2001; Moorby and Graves, 1980). It is likewise feasible that the elevated temperature facilitated solubility of mineral nutrient uptake for the reason that charge of dissolving of solutes will increase with growth in temperature (Moorby and Graves, 1980; Xu and Huang, 2006).

pH requirements

Hydroponics lettuce must be grown in a narrow pH range. In hydroponic systems, the pH constantly changes as the plant grows. pH change of less than 0.1 units insignificant. Therefore, pH control is essential in hydroponic solutions. The pH range between 5.5 and 6.5 is optimal for nutrient availability in most nutrient solutions for most species, but species vary considerably, and some can grow well outside this range de (Kreij *et al*., 2003). Optimum pH range of nutrient solution for development of plants is 5.5 to 6.5 (Trejo-Tellez and Gomez, 2016).

Conclusion

In past few years hydroponics has emerged as a promising technology for growing different crops. It favours production of short duration crops to a great extent, it allows easy production of leafy vegetables such as lettuce very quickly. Lettuce is a small herb like crop, when grown hydroponically gives better yield and quality. As hydroponics does not require land it can be used by landless people and even in metro cities where arable land is very less and availability of fresh product is limited. Hydroponics provides us an opportunity to supply fresh and quality products among all regions.

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