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Prospects of lettuce production in hydroponic agriculture: A review

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Abstract

Lettuce crop has a great importance in hydroponic Agriculture. Due to increase in population of world there are problems of foods and vegetables and conventional agriculture methods are unable to fulfill the market demand. In worldwide conventional lettuce production using soil is insufficient to meet the market demand round the year. In this scenario, alternative farming practices like Hydroponic agriculture is only feasible and have great yield promise. Nutrient film technique is one of the innovative food production system in which nutrients are circulated through root, circulating nutrients solution is important for optimum growth of the plants. The review study of different papers also indicates that there is much need of hydroponic agriculture for the optimum growth of lettuce crop and to control pest and diseases.

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Introduction

Lettuce is a crop of great importance especially due to its nutritional benefits. Its growth in traditional agriculture methods causes a wide range of negative impacts on the environment. Moreover, in traditional agriculture methods using soil there is less growth and production due to nutritional problems and other sanitation effects. To avoid these problems there is a vital need to adopt hydroponic agriculture for better growth. Lettuce can be grown in open atmosphere in soil-culture, substrates and water-culture. However, in open atmosphere year-round supply is not possible while clients demands for lettuce during off-season. For offseason lettuce growth controlled environment shed like tunnel, glasshouses and Hi-Tech greenhouses are usually constructed.

Techniques for growth of Lettuce

Due to rapid urbanization and industrialization cultivable land is decreasing and in the other hand conventional agricultural methods cause a wide range of negative impacts on the environment. To reasonably feed the world's growing population, techniques for growing sufficient food have to evolve. Modification in growth medium is an alternative for sustainable production and to conserve fast depleting land and available water resources. In the present scenario, soil less cultivation might be commenced successfully and considered as alternative option for growing healthy food plants, crops, herbs, lettuce and vegetables (Sharma *et al.*, 2018). Some factors are of great importance in vegetable production for the proper development and growth of the crop. Plant nutrition is one of the most important factors and has a direct impact on the production and quality of vegetables (Hasan *et al.*, 2017). Soil health is a crucial factor for realizing higher yield of vegetables. Excessive application of chemical fertilizers may affect soil health and sustainable productivity (Virgine Tenshia & Singram, 2005). Organic farming is appreciated by vegetable consumers as it enhances quality of the produce. Today the people are preferred to get the vegetable without the inorganic fertilizer, because they are suffering with some serious diseases which are due to the effects of chemical fertilizer (Asaduzzaman *et al.*, 2010).

Lettuce (*Lactuca sativa* L.) is a herbaceous plant that belongs to the Asteraceaes family. This leafy vegetable is consumed in Brazil and also used in other parts of world due to a good source of vitamins and minerals. Lettuce growth in NFT involves modern growing techniques and resulted in good quality and high value lettuce. These growing methods are performed in greenhouses. Nutrient solution is recirculated continuously and nutrient solution is maintained properly. From the nutritional point of view, Lettuce is a more important crop from the socio-economic aspect as it is a great source of profit for farmers Lettuce in greenhouse NFT systems based on variety requires a spacing of 8-24 plants/square meter to receive adequate light and grow optimally. With butter head types, a spacing of 10 inches on center is best to allow for full head development. (Souza *et al.*, 2017).

Lettuce growth in hydroponic agriculture has much importance due to increasing demand of lettuce in offseason. Lettuce crop also grow in a better way using hydroponic agriculture as compared to traditional cultivation of lettuce crop. This paper is mainly focused on to study lettuce production in hydroponic agriculture.

Importance of Lettuce Crop

Lettuce is an annual leafy vegetable from the family Compositae. Lettuce is one of the most famous salad crops and cultivated in the most production area among all other salad crops in the globe. Lettuce crop is well known for its delicate, crispy texture and little bitter taste with milky juice as in fresh condition. It is the most popular crop amongest the salad vegetable crops. Crops that are grown in NFT includes tomatoes, cucumbers, and lettuce. Lettuce is mostly cultivated in NFT because it is a crop of short duration and less subject to damage. Different channel widths are used for lettuce and for other leafy crops (Fenneman, *et al.*, 2018).

Temperature may affect plant growth. The most rapid growth of lettuce in a controlled environment was at 25/25°C day/night temperature. The maximum dry weight of lettuce in a greenhouse was at 24/24°C air/root temperature, and a 17°C air or root temperature resulted in less growth (Thompson *et al.*, 1998). The benefits of hydroponic agriculture are numerous. In addition to higher yields and water efficiency, when practiced in a controlled environment, hydroponic systems can be designed to support continuous production throughout the year. Touliatos *et al.* (2016) studied that Compared to traditionally cultivated lettuce, the life cycle of hydroponic lettuce is of short duration. After 35 to 40 days of growth, hydroponic lettuce may be harvested. Lettuce can be successfully grown in the NFT system and in this system it is possible to grow more than 8 crops per year efficiently. Horizontal and vertical hydroponic systems have also been analyzed with multiple nutrient solutions for lettuce yield optimization. Lettuce is grown almost exclusively for the fresh market for salads, sandwiches and as a garnish. Its production in greenhouses has become popular and potentially a profitable venture. Greenhouse lettuce is grown primarily in soilless media, using rookwool, perlite or a hydroponic nutrient film technique (NFT) (Elmhirst 2006, Morgan & Tan, 1983).

Hydroponic lettuce is produced either through nutrient film technique (NFT) or the floating raft method, both as closed systems. The major advantages of hydroponic lettuce include a short production period (35-40 days), availability year round, and consistency of product attributes. Production of greenhouse lettuce requires strict control of temperature, light, carbon dioxide concentration and relative humidity (RH) (Sabir & Singh, 2013). Lettuce is one of the most important specialty crops produced and distributed in the United States. Currently it is the leading vegetable crop in terms of production value. In addition, the U.S. is the leading exporter of lettuce, with 327,268 MT exported in 2010. During the past five years, per capita consumption of romaine lettuce in the United States has increased nearly three-fold that of consumption 20 years ago. The main types of lettuce are heading lettuce (iceberg, butterhead, Boston, and Bibb), romaine (Cos) and leaf lettuces. Heading lettuce and romaine varieties, make up the majority of lettuce production. They are typically produced in raised beds, covered with black plastic mulch and provided drip irrigation. A crop usually matures in 65-70 days (Smith, 2009; Wahid, 2007). Growth is dependent on sufficient nitrogen availability. Lettuce typically requires 100-120 lbs N per acre, however, total N uptake in the first 30 days is very low (Smith, 2009). Therefore, best management practices require careful water and nutrient management.

Lettuce is a cool weather crop which is especially sensitive to heat stress and day length—thus limiting the regions and environmental conditions under which it can be grown. Virtually all plant species have a heat-stress threshold, above which they exhibit morphological, anatomical, and phenological effects, as well as physiological responses including changes in water relations, photosynthetic ability, hormones and secondary metabolites (Wahid, 2007). Threshold temperatures and specific responses vary with plant species and developmental stage.

Lettuce seeds are extremely sensitive to heat, typically having a lower heat-threshold than developing plants. Thermoinhibition occurs for seeds imbibed at temperatures greater than 25-33^{0}C (77-91^{0}F) (Argyris, 2008). A common practice used to overcome this, especially in the lettuce-producing Imperial Valley of CA, is to sow seeds during the day and then water in the evening so that early stages of germination take place in soil cooled by evaporation (Janick, 1992). These solutions are not feasible in places with high nighttime temperatures.

Variety trials in various places around the world have evaluated days to flowering and identified suitable cultivars for heat tolerance and other climactic challenges (de Souza, 2008; Simmone, 2002). Dufault *et al.* evaluated approximately eight planting dates for seven lettuce cultivars to be used in long term commercial lettuce production in South Carolina. Simonne *et al.* tested seventeen cultivars for production in the Southeastern United States, identifying suitable cultivars based on earliness to flower and bolting, consumer perception, and antioxidant content (Simonne, 2002). However, these same researchers explain that variation in quality 'are numerous and are a result of complex genetic, physiological, and environmental influences,' making it extremely difficult to know how specific cultivars will perform under climatic conditions of different regions and growing seasons. Suitable cultivars and planting dates are therefore dependent on local conditions.

In a preliminary planting in the same year, nine cultivars of heat-resistant iceberg and romaine heading lettuce were grown at the Wye Research and Education Center on the Eastern Shore of Maryland. Cultural practices were also implemented to increase time to flower and bolting, including reflective plastic and evaporative cooling with the goal of reducing soil and air temperatures. A number of these California cultivars showed great potential and are being evaluated in current research.

There is great demand in the Mid-Atlantic for local, heat tolerant lettuce cultivars. Successful production of lettuce in this climate would justify the establishment of a large-scale lettuce production industry. Reducing miles travelled by refrigerated vehicles is much more economical for farmers and reduces consumption of fossil fuels. The belt of farmers in the Mid-Atlantic region already producing summer leafy greens-mostly spinach and kale-demonstrates that there is land available for farming. In addition, a new production industry necessitates the establishment of new processing plants which will provide more jobs, economic benefits to the area, and reduced cost to processors and distributors. Warm climate lettuce production also has the potential to benefit small scale productions by providing growers with another marketable summer crop. In light of the growing local food movement, consumers will be happy to see another local vegetable in their markets and CSA baskets. However, all this is contingent on identifying cultivars suitable for the Mid-Atlantic summer climate.

Worldwide growth of Lettuce

The Agricultural Marketing Resource Center shows that there will be an increase by 1/4 of all lettuce produced and marketed for human consumption. The United States Department of Agriculture (USDA) Economics, Statistics and Market Information System claims that 72, 178 million pounds of lettuce were produced, sold, and utilized in other ways as of 2010. This Production is generally in considered a cool-season crop between 73°F and 45°F, however, hydroponic greenhouse practices are changing this production cycle to a more productive time period (s) where it will be available throughout the year globally. Farmers, families, and companies will be able to select more specific time limits and harvesting periods. He confirmed that California and Arizona are at the top of the production list in the United States with California producing 71 percent of the head lettuce in the US in 2013 and Arizona about percent and the two states grow about 98% of the leaf lettuce nationwide.

According to the USDA, in their 2012 updated Census of Agriculture, lettuce occupied 323,359 acres and increase of 3% since 2007 (USDA, 2012). The number of farms increased by 38% from 2007 and 2012 and the demand is still high. In California, the tonnage for lettuce was as follows per acre: 20 tons' iceberg, 15 tons for romaine, and 12 tons for leaf lettuce. According to their calculations, the overall US production in 2014, the latest Fig.s in this research, was 3,881 million pounds, about 12% of that amount exported to other countries, islands, and 169.7 million pounds imported to the US to keep up with demands.

Dickerson (2016) of New Mexico State University (NMSU) showed that Greenhouse Vegetable Production via hydroponics is in higher demand and is increasing in the Midwest especially during the non-summer months. He showed that the Greenhouse's location, construction, temperature control, soil culture, hydroponic culture, crops and culture, carbon dioxide enhancement, integrated pest management, and other factors are all very important. According to Dickerson, lettuce prefers low daylight temperatures at about 60°-65°F and a night temperature of about 50°-55°F for the fall and spring crops. If the temperatures are too high in the greenhouse or too low, they can damage lettuce. Generally, it takes 30 days for the leafy lettuce to grow from seed to appropriate size for transplanting them to permanent locations.

Dickerson affirms that it takes 12-15 weeks during the winter months and 8-10 weeks during the spring months to grow. They confirm that lettuce feeds poorly and needs normal soil, fertilizer, and/or hydroponic care for proper growth. Leaf and Bibb lettuce are most acceptable but all types of lettuce will grow successfully in a hydroponically controlled environment.

Yahia, E. (2005) states that Post Harvest Technology in the Near East and North Africa (NENA) regions regional growing differences exist but millions of acres of lettuce are grown in countries with drastically varied GNP's: $19,020 in Kuwait, Sudan $330, $350 in Yemen, $470 in Pakistan, $1,500 in Jordan, $3,700 in Lebanon, and $17,870 in the UAE. He confirms that regional cooperation in growing food could greatly impact the food gaps. However, research in the areas, especially in the NENA region is scarce confirming that there is a need for quantitative research and crop issues. In these NENA and other regions, it is commonly known that more than 40,000 people starve to death a week due to a lack of food and thus this research is extremely valuable in underdeveloped and war-torn regions. There is a critical need for more food in the areas where about 35 Million metric tons (mmt) of cereals was grown in 2010 but 55mmt were consumed. There is a need for 80mmt of fruit and vegetables and only 53mmt were produced in 2010. Agricultural trade balance in the Maghreb sub-region is negative. Thus, there are negative balances in food in numerous countries globally and some import from 30–60% of their food. Various researchers studied field nutritional status methods to determine the mineral content of the soil and plants.

Effect of Light in Hydroponic Agriculture for Lettuce Growth

Globally, all plants need various amounts of light for maximum growth and lettuce is one of the more delicate plants that must be exposed to the proper amount of light and not too much. Lettuce plants also need the right amount of water, restricted use of chemicals, and proper care for human consumption. According to the United States Department of Agriculture (USDA) Economics, Statistics and Market Information System, 72, 178 million pounds of lettuce were produced, sold, and utilized in other ways in 2010. In Head and other lettuce monthly export volume, 1990-2010, the government showed the critical need for lettuce globally. Successfully growing Hydroponic Organic Lettuce *Lactuca sativa* in greenhouse settings under Supplemental lights vs. No Supplemental lights or normal sunlight can fill marketing needs in Colorado, the Middle East, and dry and arid regions globally. However, there is a critical need for efficient, new, controlled, and profitable methods to meet the public demands for lettuce. Hydroponically grown lettuce in greenhouses under Supplemental lights vs No supplemental lights is one methodology for improving the crop yields and success of lettuce production. This method can fulfill the need to control the environments and produce lettuce throughout the year in a manner that has never been equaled globally. Thus, utilizing different forms of lights is worth investigating to determine if Supplemental lights vs. No supplemental lights can aid in improved lettuce growth with less trouble. Light becomes more important in the growing of lettuce and we need to determine if Supplemental lights vs. No supplemental lights have a significant effect on the quality and mineral contents of the final plants. Plants exposed to Supplemental lights may grow in less risk than in sunlight and improve the global production of lettuce worldwide under improved agricultural and horticultural conditions.

According to the Urbonaviciute, A., Pinho, P., Samuoliene, Duchovskis, P, Vitta, P.,Stonkus, A., Tamulaitis, G., Zukauskas, A., and Halonen, L. (2007) and the Lithuanian Institute of Horticulture and Lithuanian University of Agriculture (2007) the length of light rays effects on growth and development of lettuce, its maturation processes, growth, and nutritional qualities. It also affects the nitrites and sugars in the plant. The results of this study showed that lettuce can be affected by Supplemental lights and No supplemental lights variables and when those lights are modified and the length of the lighting exposure is extended or decreased, it alters most qualities of the plant.

Urbonaviciute, A., *et al.* (2007) also proved that it affected carbohydrates. In support of this research, pfaf.org (2016) states Lactuca sativa has nutritional, medicinal, and other valuable qualities. It is an annual/biennial that is short by nature at 0.9m (3ft) by 0.3m (1ft in), and was probably one of the first perennials transferred to America from the UK where it grows hardy and is not frost sensitive or tender. Generally, it flowers in the late summer months of July to August but the seeds reach maturity from Aug to September when grown in outdoor climates. It is a hermaphrodite plant with male and female organs and is pollinated by flies or self-fertilized. It can grow in slightly light (sandy) to medium (loamy) soils but it prefers the soils to be well drained and not waterlogged. It also grows well in neutral and basic (alkaline) soils but can grow with or without shade in moist soil. Globally, the milky substance in lettuce is considered valuable and hence increases the need, marketability, and global demand for the product.

According to Khairy, H. and El-Sheikh, M. (2014) the mineral contents of plants are affected by the amount of light they receive or do not receive. In section 3.5. (Minerals composition) of the article, the authors affirm that Sodium (Na), Potassium (K), Calcium (Ca), and Magnesium (Mg) are among the minerals affected by the light sources. Thus, the mineral contents varied according to the light, light wave exposure, seasons of the year, environmental factors, physiological factors of the plant, and mineralization practices. They also confirm that light and other factors affect calcium levels in the plant, Na, K, Ca, Mg, and the contents of these macro elements, though in small amounts, the mineral contents varied by the seasons. The authors in another study, Hecher, E., Falk, C., Enfield, J., Guldan, S. and Uchanski, M. (2014) explained the importance of greenhouses used in this study are called Low-Cost High Tunnels or Hoop Houses with controlled environments, lighting, hydrophonics, and other variables. In the Economics of Low-cost High Tunnels forWinter Vegetable Production in the Southwestern United States they showed the need for Low-cost greenhouses in the Southwestern United States where farmers, small farmers, and families can better control the lettuce, risk, extend and alter the growth season, simulation models, and crops. They firmly established the need for these low cost hydroponic houses with controlled Supplemental lights vs. No supplemental lights to effectively grow lettuce. They affirm there is a critical need and little valid and in-depth research from the past 10 years regarding Supplemental lights vs. No supplemental lights in the Midwestern United States for small scale farmers. This study specifically focused on *Lactuca sativa*. This was a Single Layer (SL) and Double Layer (DL) study of lettuce and spinach. This study also confirms that the cost factors makes Hydroponic greenhouse growing profitable. In the sensitivity analysis for lettuce growth, the researchers confirmed that the SL design was more profitable than the DL design for lettuce where a group of lettuce plants has another group or layer under it.

This process of growth was thought to be more efficient but it was not. The lettuce growing and the projects were more successful than lettuce grown in the open, arid, and dry sunlight and direct heat. Likewise, it gave farmers more flexibility in planting in that they determined that the planting date were not a factor in yield, profit, and success in thegreenhouses, the farmers/growers were free to select their own planting dates, times and seasons with much flexibility. The result was higher yield with lower cost for the SL lettuce production grown in hydroponic greenhouse with Supplemental lights vs. No supplemental lights.

There can be random and personal changes to the growing seasons in greenhouse scenarios at a person's discretion and choice. This makes it more inviting, manageable, and profitable for farmers or families to manage their profits and losses when raising lettuce in a greenhouse setting with Supplemental lights vs. No supplemental lights and lower the risk of crop losses (Hecher *et al*, 2014).

Preparation and transitioning to Supplemental light vs. No supplemental light with Hydroponic Greenhouse Models required a hearing before congress of the United States. Thus, the transition is and has been expensive due to the political red tape but it is a transition that needs to take place for desert and arid areas of the United States and small farmers/families to grow lettuce with minimal cost. In this research and others, the NCES (2016) used Supplemental lights vs. No supplemental lights as the Dependent Variables for growing lettuce. Likewise, Resh, H. (2012) and the National Center for Educational Statistics (NCES, 2016) investigated Independent Variables (IV) and Dependent Variables (DV) to determine the validity and reliable facts regarding the Supplemental lights vs. No supplemental lights. The success or findings of Hydrophobic Greenhouse experiments and mineral retention in lettuce was clear. According to the NCES, the IV, Supplemental lights, stands alone, is not altered, changed by the DV (Lettuce) or other variables one is measuring. This shows that the Hydroponic food production for the home gardner and larger commercial hydroponic growers has tremendous ramifications globally in the restructuring of when, where, and how food is grown and marketed at minimal cost and varied amounts. This process of using Supplemental lights vs. No supplemental lights was used by White, T. (2014) as a successful prototype for growing food under Supplemental lights in an environments and high-rises, skyscrapers, and giant barges.

They confirmed that the amount of Supplemental lighting vs. No Supplemental lighting can cause a change in the DV (lettuce quality, size, etc.) and it isn't possible that Dependent Variable (lettuce) could cause a change in the IV (Supplemental lights) (NCES, 2016) and those changes can last up to 10 years according to previous researchers. According to Massa, and Wheeler (2010), plants responded to light-emitting diodes (LEDs) and have tremendous potential for lettuce and other crop production. The benefits of the Supplemental light vs. regular light, traditional lighting, sunlight, no Supplemental light, and other forms outweigh the negatives. The output of the narrow LEDs (single color, no phosphorcoated) vs. the traditional sources of electricity and the ability to alter it is essential and profitable for certain crops. The Supplemental lights can be blue, red, white, and/or a combination of all three and each has its benefits and restrictions according to this research and that of all the other Supplemental researchers. This article reported data from more than 30 researchers showing supplemental lighting is valid and reliable sources vs. No supplemental lighting or Regular light, Sunlight, and other traditional sources. They confirmed too that it is less expensive, controllable, and the planting, growing, and harvesting timelines can be altered.

The findings reported by Massa and wheeler (2010) affirm that Supplemental lights can be harnessed, used, modified, altered, and in other ways controlled to show their superiority over No supplemental light, Regular light, and uncontrollable sunlight. Okamoto, K., Yanagi, T., Takita, S., Tanaka, M., Higuchi, T., Ushida, Y. and Watanabe, H. (1996), while beyond the 10-year time limit for this research, introduced one of the key apparatuses that proves that Supplemental lights contribute to the photosynthesis of plants. Several of the best research findings, discoveries, theories, and articles regarding horticulture, agriculture, and lighting are outside the 10-year limit for current research. They introduced the "LED PACK, BIOLED, UNIPACK, and COMPACK" machines that were vital in proving the impact that Supplemental lights have on the overall functioning of the plants and their growth, retention of minerals, and other nutrients from the soil or water. One of their methods for proving this was the use of the exact type of lettuce in this study. The purpose of their study was to introduce the plant growing apparatus that used.

Supplemental light and to evaluate No Supplemental light sources for normal and not defective plant growth. Lettuce seedlings were used and (Lactuca sativa) hydroponically grown for 14 days and growth successfully accelerated. Thus, Supplemental lighting vs. No Supplemental lighting in producing lettuce and other crops can be the solution to the global population crises where starvation is by product of that explosion and have a positive effect on reversing starvation statistics globally. As a result of these findings, the following normal areas for planting are reduced drastically in favor of reducing this space and controlling the elements with hydroponic greenhouses with Supplemental lights vs. No Supplemental lights as the only or primary light source. Asknumbers.com (2009) show there are 43, 560 square feet in an acre and one square ft holds four head of lettuce. However, if you separate the rows or plantings by three feet and have only 2 heads per 1 x 3 square feet, it makes growth and working around the crop easier. Thus, we deci Testing for Minerals: What is ICP-MS did to divide the harvest area by 1/3 or 14, 520 feet of rows in the acreage and about 7, 260 in the ½ acres to make planting and working around the lettuce easier. Thomasnet (2010) and Huang, (2016) shows that there are generally 20-24 heads per box in a corrugated box that is Size: 16"W x 24-1/4"L x 91/2"H, and they are priced at about 1- 249 cases $2.18 per head to 1250 can be as low as $1.82 / head of lettuce.

Organic v/s Hydroponic Growth of Lettuce

According to Sakhi, Ms, D., Arabella, H., Ms, A., Aikenhead, E., Allen, K. and Lock, R. (2009) there is a lot of research and consideration of organic vs. synthetic or organically vs. conventionally produced foods and their benefits and this is confirmed by a systematic review of literature by nutriwatch (2009). There are arguments for and against organic vs. synthetic growth processes and vegetables. The authors claim there are little differences in the nutrient content of the two growth processes for certain vitamins and minerals such as: vitamin C, calcium, potassium, phosphorus, soluble solids, copper, iron, manganese, sodium, plant carbohydrates and other minerals. They affirmed that in some cases there were significant differences in the minerals and element contents of the varied growth processes. In the major nutrients addressed, most of the organic crops had higher mineral contents.

In the systematic reviews, Paull, J., Kristiansen, P., & Hill, S. (2013) showed that organic farming has grown from 15.8 million hectares to over 37.2 million hectares globally in 10 years. Organic farming encompasses numerous restrictions on what can and cannot be used to classify gardens as organic but these also include a limited use of some synthetic fertilizers and chemicals. They show that India ranked seventh globally with 1.2 million hectares of approved and recognized organic agriculture or about 0.6% of its cultivable area. Hollyer, J., Brooks, F., Fernandez-Salvador, L., Castro, L., Meyer, D.,Radovich, T., (2013) showed that certain conventional fertilizers, pesticides, and synthetic or non-organic substances are used in U.S. farming. Under the USDA National Organic Program,

Hollyer (2013) affirmed that certain synthetic, and conventional pesticides and fertilizers are allowed in gardens labeled as organic in the marketing strategies. There are numerous factors that govern the organic vs. synthetic label and consumers should be very diligent in assuming what they purchase and the real facts regarding the comparisons. The governing authorities have allowed non-synthetic and synthetic fertilizers to improve soil fertility, organic farming, and plant health. There are laws govern this and the rules are different for conventional farmers vs. organic farmers.

Common citizens consider organic foods as those are natural and prevention some illnesses, increase the quality of life, are organically grown foods vs conventionally grown foods. There are many misconceptions of classifying foods as organic vs synthetic and people need to make sure that the classifications are clear. Some of these reasons include (1) few or no pesticides (2) organics are gentler (3) they believe organics have more nutrients. Thus, organically grown does not necessarily mean free of all toxins used in plant and animal production, according to Paull, J., Kristiansen, P., & Hill, S. (2013), there is much to understand about organic vs synthetic growing and one has to be very familiar with the production and growth process or grow it and control the process personally or know the people who are controlling it as in China.

Despite its high demand for energy, hydroponics remains a promising technology. Several factors could influence the feasibility of hydroponic production of crops, specifically lettuce. As more sophisticated control devices become available, the cost of maintaining the controlled environment of hydroponic greenhouses could decrease.

The future availability of water, land and food will also influence feasibility through increased demand. Increasing land and water scarcity will make the more land- and water-efficient hydroponic systems. Hydroponic farming provides promising concepts that could lead to more sustainable food production. In summary, hydroponic gardening of lettuce uses land and water more efficiently than conventional farming and could become a strategy for sustainably feeding the world's growing population (Barbosa *et al.*, 2015).

Greenhouses production of Lettuce using Hydroponics

Controlled environments (CEs), such as greenhouses, are increasingly being used to grow fresh produce such as tomatoes, peppers, cucurbits, melons, berries, and salad greens (Parry *et al.*, 2004). The greenhouse food crop industry in the United States was estimated to have grown 3 billion USD worth of produce in 2012 and is projected to grow over 4 billion USD by the year 2020 (Rabobank, 2013). In 2012, 1.5 billion USD of this total revenue was attributed to greenhouse grown salad greens, including lettuce, and over 1 billion USD to tomatoes (USDA, 2011).

With over 8000 total hectares of commercial greenhouses in the U.S. (USDA, 2011), growers and consumers are taking advantage of the produce quality, crop consistency, and resource usage efficiency that CEs can provide. Greenhouse production reduces the economic barriers for entry into farming, such as the purchase of agricultural lands and heavy farming equipment. Moreover, small operations may be economically viable in niche markets due to year round production of high value crops. Greenhouses can be tailored to meet the needs of practically any grower and even allow them to cultivate crops on non-arable land, such as deserts, brownfields, and urban rooftops. Introducing crops into CEs, such as greenhouses, can have numerous additional advantages over conventional field production, including giving growers the ability to monitor the plants' water usage (Giacomelli, 1998; Jones and Tardieu, 1998) and irrigate with maximal efficiency using capillary mat, ebb-and-flow, or drip irrigation systems, for example (Beerling *et al.*, 2014; Stanghellini, 2014). Greenhouses also offer climactic control (Durazzo *et al.*, 2013) and physical protection against weather conditions and pests that have been known to damage outdoor crops and reduce yield and quality (Parry *et al.*, 2004; Rosenzweig *et al.*, 2001). Pests and diseases, however, present a challenge even in greenhouse systems. In certain regions, greenhouse crop cultivation also may help to avert heavy metal toxicity in produce due to contaminated agricultural soils (Chang *et al.*, 2014).

While shading has been found to reduce greenhouse temperature and crop transpiration (Kitta *et al.*, 2012), it is also an effective means of reducing light intensity in cases where it exceeds the light saturation point so as to reduce potential damage to the crop. Shading may also be used to limit the Daily Light Integral (DLI) as well as the photoperiod. Conversely, supplemental lighting applied to a greenhouse crop may serve to extend the photoperiod or increase the intensity of Photosynthetically Active Radiation (PAR). Various types of light sources have been tested in the greenhouse setting, including High Intensity Discharge (HID) lamps and Light Emitting Diodes (LEDs). Both HID lamps, such as High Pressure Sodium (HPS) bulbs, and LEDs have shown potential in growing and supplementing crops and the next generation lighting technologies promise to increase energy efficiency, uniformity and photosynthetic efficacy in greenhouse crop cultivation. Since all of these technological advances are easier to apply to greenhouse crop production than field crop production, they give greenhouses additional advantages over field production.

Integrated pest management (IPM) is generally considered to be the strategic combination of control strategies including bio-control agents (BCAs), physical protections, and agricultural control chemicals to minimize potential ecological effects. While IPM is generally considered a success within the field of CE agriculture, the effectiveness of the strategies employed rests on available technology as well as crop species and cultivars. The main advantage to Integrated pest management (IPM) that greenhouses provide is that physical controls, such as screens, climate control, and resistant cultivars, enhance the efficacy of biological and chemical controls (Ponce *et al.*, 2014). For example, predatory insects confined to the intended crop by the greenhouse structure more effectively control the population of their prey insects than if they were applied in an open field.

In addition, applications of pesticides and fungicides in a greenhouse can be more effective and long-lasting than in the field due to the reduction of new pathogen and pest infiltration and prolonging of residual activity. Although field and greenhouse applications of BCAs have not been shown to achieve the success rates that laboratory trials do (Freckleton, 2000), a BCA is considered effective if it can suppress a pest or pathogen enough to provide sufficient crop protection to ensure that yield and quality are minimally affected. Real-time greenhouse temperature and humidity mapping, using sensors, helps determine the effect of abiotic factors on biotic interactions between crops, pests, and beneficial organisms (Fatnassi *et al.*, 2006). New strategies must continuously be developed to manage the emergence of pest and pathogen resistance, as well as the removal of various chemical agents (Wezel *et al.*, 2009).

Despite the advantages of greenhouse cultivation, there remain concerns that need to be addressed. Consumers are increasingly demanding produce that has been grown with ecological considerations (i.e. with a small carbon footprint and little to no use of agricultural chemicals such as pesticides and fungicides) as well as high quality food for the lowest price possible. This, in turn, means that greenhouse crop growers must continue to reduce their use of resources, reduce their waste levels, and increase productivity through better greenhouse design and management practices that focus on the optimization of efficiency and the early detection of sources of plant stresses that may reduce yield and quality (Stanghellini and Montero, 2012). The development of innovative greenhouse glazing materials will further improve energy conservation, diffuse lighting, allow spectral selectivity, and minimize pest pressure. Moreover, the use of renewable energy sources such as solar, wind, and geothermal power will decrease energy costs and increase operational efficiency and overall sustainability of greenhouse crop cultivation.

Cultivated lettuce, is a diverse species with numerous cultivars and is derived from *L. serriola*, its wild counterpart, through cultivation. *L. sativa* is an annual angiosperm that belongs to the Asteraceae family. *L. sativa* is a dioecious plant, with each individual displaying either male or female flowers exclusively and flower stalks reaching one meter in height. Individuals can continue flowering for up to four weeks, commonly opening flowers in the morning and closing them in the evening. A single female plant can produce dozens of viable seeds. Lettuce is currently cultivated around the world wherever temperate climates or microclimates and cool seasons are experienced or can be simulated. The global production of lettuce in 2013 totaled almost 25 million tons, with China, the United States, and India producing 13.5, 3.6, and 1.1 million tons, respectively. Lettuce is produced extensively in the United States both in the field and under greenhouse structures either in soil, soilless media, or hydroponic systems. The lettuce produced in the U.S., on over 130,000 hectares, was valued at a total of $2 billion and the vast majority of production took place in California and Arizona and was subsequently distributed across the country (USDA, 2012).

Commercially, lettuce is produced from seed that is propagated by companies dedicated to breeding, maintaining, and propagating select cultivars. Lettuce can also be rapidly regenerated and propagated asexually by tissue culture. Optimal germination of seed occurs around 25°C, and germination rate decreases steadily as the temperature is decreased. Temperatures over 27°C inhibit seed germination as well as plant growth. Optimal vegetative growth for most cultivars has been observed between 16°C and 18°C, and most tolerate temperatures as low as 7°C. The ideal pH range for lettuce production was found to be between 6.0 - 6.7 in field production and 5.6-6.0 for hydroponic production (Morgan *et al.*, 2012). Bolting, and subsequent flowering, is promoted by temperatures above 20°C, as well as long days, and can often be mitigated by shading plants from full sunlight or cooling the root zone by chilling the fertilizer solution or irrigation water (Morgan *et al.*, 2012).

Heads of lettuce are generally harvested by hand; in the field, the shoot is cut at the base and the roots are left in the soil, while hydroponically grown lettuce heads may be cut but are often pulled from the cultivation system, packaged and sold with the roots intact. Living lettuce that still has an intact root ball can stay turgid and appear fresh for up to two weeks when refrigerated, as compared to one week or less for field-grown or processed lettuce. The limiting of oxygen and control of relative humidity is crucial for lettuce storage and transport, and nitrogen gas is often supplemented in packages of cut lettuce produced for supermarket sale.

High value cultivars of lettuce (e.g. romaine, oakleaf, bibb, butterhead types) are increasingly replacing crisp-head varieties (e.g. iceberg) at cultivation facilities (Morgan *et al.*, 2012) due to their aesthetics, textures, and nutritional qualities. These cultivars are being incorporated into greenhouses for soilless or hydroponic production due to their high aesthetic, nutritional, and economic value (Davis *et al.*, 1997; Morgan *et al.*, 2012).

Hydroponics is the cultivation of plants without the use of soil, either in sterilized containers of dilute fertilizer solution or in inert soilless media that is irrigated. Most hydroponic systems involve the recirculation of fertilizer solution. Hydroponic cultivation allows growers to control the fertilizer regimen and root zone pH (Savvas, 2003), which can be monitored and controlled automatically in real-time (Domingues *et al.*, 2012; Jung *et al.*, 2014) with the use of sensors and injectors. Moreover, hydroponic systems can provide numerous potential advantages over field production, including the ability to separately regulate the shoot and root temperatures, which is not possible under field conditions. The fertilizer solution is often heated or cooled to a different temperature than that of the ambient or greenhouse air, and this helps provide crops with optimal conditions for growth (Thompson *et al.*, 1998). It also enables growers to meet increasingly strict regulations on water and fertilizer usage and runoff (Beerling *et al.*, 2014) as well as contribute to sustainable food production practices and food security.

Many other diverse benefits of hydroponics have been reported. For example, the nutritional quality of lettuce and soybean has been improved using hydroponic cultivation when compared to conventional production methods (Bito *et al.*, 2013; Palmero *et al.*, 2011). These production systems also help growers avoid food contamination by human pathogens, such as *Escherichia coli* and *Salmonella enterica* (Franz *et al.*, 2007) and even allow the roots to be protected from pathogens during cultivation by using organic additives (Chinta *et al.*, 2014) or carbon dioxide (Kobayashi *et al.*, 2013). Furthermore, bacterial inoculation of hydroponic fertilizer solutions can degrade excess ferulic acid, released from plant roots, which inhibits root growth. Many of these advantages contribute to higher yields per area in addition to the fact that hydroponic crop cultivation does not require any arable land.

Aquaponics is the cultivation method linking the production of fish to the production of crops. In addition, hydroponic cultivation systems have allowed growers to utilize brackish water, a mixture of fresh and salt water, to grow crops. In effect, hydroponics serves as a technological tool that supports greenhouse crop cultivation. Hydroponics facilitates the application of integrated crop management strategies (Savvas, 2003), which generally include soil conservation, biological control, and minimal use of non-renewable energy sources.

The nutrient film technique (NFT) has been used as a method of hydroponic cultivation since the early twentieth century and has become the most common hydroponic method for the production of salad greens and herbs (Morgan *et al.*, 2012). It makes use of long troughs or tubes sloped at a 2-3% decline. Hydroponic fertilizer solution is fed into the high side of the troughs through an irrigation manifold that is pressurized by a pump in the reservoir.

The solution moves down the troughs as a shallow liquid film (2-3mm deep) and is collected by a gutter at the low end that transports it back to the reservoir (Smith, 1999). The troughs used in NFT hydroponic systems are usually made of food grade PVC (polyvinyl chloride) and can range from less than 1.5m to over 20m in length (commonly 2 - 4m in length); they can be circular or rectangular cylinders.

Seedlings in their germination cubes or plugs are placed into holes on the top side of the NFT troughs and rest on the bottom surface, where their roots lay flat and are wetted by the recirculated shallow film of nutrient solution. Despite the diffusion of oxygen being maximal into a shallow film of liquid, the fertilizer solution will equilibrate with the temperature of ambient air, which may be too hot to allow sufficient diffusion of oxygen from the air. Therefore, the fertilizer solution is commonly chilled in hot climates or seasons, and a venture device is usually used when cultivating plants in an NFT system. A venturi supplies additional oxygenation to the solution in the reservoir (Smith, 1999); it functions by using negative pressure caused by the flow of solution through a pipe to inject air bubbles from an adjoining smaller tube in contact with ambient air. When using an NFT system, a grower must check and adjust the reservoir water level, the electrical conductivity (E.C.), and the pH of the fertilizer solution daily to within the desired ranges. This can be done manually or automatically with the use of chemical dosing machines. This hydroponic method is also compatible with aquaponic crop production in that aquaculture effluent can be used as the recirculating fertilizer solution.

The limitations of this system include pump failures, which may result in rapid wilting damage to the crop due to the absence of a humidity buffer. Warm fertilizer solution cannot dissolve as much oxygen, and gradients in temperature, oxygen, and fertilizer can occur down the troughs, especially when troughs are relatively long. Clogs in the feed line micro-tubing may also result in isolated trough dry-outs due to algal accumulation constricting nutrient solution flow in the narrowest components. When using NFT systems for crop production, it is vital to maintain an alternative source of power and it is recommended to minimize the exposure of the nutrient solution to light so as to inhibit algal growth.

The effect of the potting media on water uptake and distribution during irrigation has been simulated for ebb-and-flow irrigation (Anlauf, Rehrmann, & Schacht, 2012), and the depth, duration, and frequency of flooding affect the moisture levels of the growing substrate. The frequency and duration of flooding are controlled with electronic timers, and the depth is determined by the safety drain adjusted to the desired height. Ebb-and-flow irrigation benching has been used to grow potted herbs, but not to grow lettuce. However, due to its versatility, ebband- flow benching can potentially be used for novel applications, such greenhouse lettuce production. The performance of this system and the growth and development of lettuce depend on the substrate used, the depth of the substrate, and the frequency and duration of irrigation. Therefore, we sought to evaluate different aggregate depth and irrigation frequency treatments, using expanded clay aggregate, to optimize the SAEF system before performing a side by side comparison with the NFT and DFT systems.

Lettuce Growth in Pakistan

Pakistan's economy is based mainly on agriculture which contributes 18.9 percent in GDP and employs 42.3 percent labour force. Total GDP of agriculture sector remained Rs. 2336 billion with growth rate of 3.81 percent during 2017-18 (GoP, 2018). Vegetables and fruits are grown in almost all provinces of Pakistan. Gross value added of fruits and vegetables during 2014-15 was Rs. 537 billion at current basic prices, out of which 34 percent was contributed by vegetables and 66 percent by fruits. During 2014-15 vegetables were sown on 437.1 thousand hectares in the country as against fruit cultivation on 775 thousand hectares. Punjab is the dominant province in supply of vegetables. Total area under vegetable cultivation in Punjab was 300 thousand hectares during 2014-15 which constitutes 69% of the total vegetable area of Pakistan following Sind, KPK and Baluchistan (GoP, 2016a).

Agriculture productivity stagnation is a worldwide phenomenon. Many econometric studies have focused on productivity stagnation in the agriculture sector (Frisvold & Ingram, 1995; Ghura & Just, 1992; Haley, 1991; Kawagoe, Hayami, & Ruttan, 1985; Lileeva & Trefler, 2010; D. Nguyen, 1979). Productivity measures sectoral efficiency in the use of factors of production like land, labour and capital. Estimation of agricultural production function and land and labor productivity remained the analytical point of different studies. Various sources of agriculture productivity stagnation in Pakistan were also analysed in some studies (Ahmad, 2001; Saleem & Jan, 2011). Climate change and severe climatic conditions are further deteriorating the situation.

Pakistan is facing serious issue of vegetable yield stagnancy during last many decades. During 1971, vegetable yield was 11.76 ton per hectare which increased to a maximum of 15.27 during 1997 and then decreased to 12.39 tons per hectare in 2016 as reported by Food and Agriculture Organisation (FAO, 2018). In Agriculture Statistics of Pakistan, Government of Pakistan reported yield of vegetable as 10.95 ton per hectare during 1997-98 which further decreased to 9.48 ton per hectare in 2014-15 (GoP, 2016a). Pakistan's average yield of vegetable is very low as compared to world average. Crop specific yield gap is also dominant feature of Pakistan's agriculture. There is a wide gap of yield of tomato in Pakistan which is around 10t/ha in open field (GoP, 2016a) and the world average of 34.69 t/ha (FAO, 2018). This is mainly due to traditional system of production. Adoption of high tech. system can support Pakistan to enhance its productivity and ultimately global food security.

Demand of food is rising globally (Tilman, Balzer, Hill, & Befort, 2011). High growth rate of population, urbanization and increased purchasing power are contributing positively in increasing demand of food in the country. Per capita consumption of food is high in urban areas as compared to rural area. This also required more demand for food. World population is also increasing which need increased supply of food as a global responsibility.

Total area of Pakistan is 79.61 million hectare (m.ha.). The cultivated area is 22.06 m.ha., which is stagnant over many decades (GoP, 2018). The increase in vegetable production is mainly attributed to the crop trade off in agriculture sector. The horizontal expansion to increase supply of food has limited scope. Option left with Pakistan is vertical expansion i.e, increased per hectare productivity of each crop. Increasing yield is only possible through adoption of modern technology (Nguyen & Gizaw, 2014).

Importance of Hydroponic System for Lettuce Growth

Among most modern techniques for increasing productivity, hydroponic is the potential technology to adapt. The production of fruits and vegetables could increase manifold in hydroponic system. Hydroponics is a method of growing plants using mineral nutrient solutions, in water, without soil. Hydroponics is a successful and rapidly expanding industry in the world over and is recognized for manifold productivity improvement in developed countries especially in Australia (Carruthers, 2002).

Hydroponic technology is a capital-intensive technology involving development of infrastructure which has positive impact on productivity and growth (Imran & Niazi, 2011). US department of labour classify food crops grown under cover as 0182 sub-head of major Agriculture production as 01 (USDL, 2014). Hydroponic is capital intensive technology (Jensen, 1997) as against tradition agriculture which is labour intensive. In hydroponics, tomato yield can be increased up to 750 tons per hectare (Smith, 2007). Average yield of tomato obtained in hydroponics production system in Pakistan was 162 ton per hectare (Malik, Mughal, Mian, & Khan, 2018) as compared to 10 ton per hectare in open field (FAO, 2018).

Pakistan has comparative advantage in the trade of fruits and vegetables. The revealed comparative advantage index of Pakistan for vegetable was 1.2 and for fruits 1.75 from 1999-08 (Riaz, Jansen, & Malik). Total exports of vegetables of Pakistan was US$173 million during 2017 as against world trade of US$71.7 billion in the same year. The export of fruits HS code 08 was comprised of US$ 707.8 m during 2017.

The import of vegetable of Pakistan comprising of HS code 07, were 981m US$ and that of fruits US$ 702 m (ITC, 2018).

Lettuce consists one of the most important cultivated vegetable in Greece, contributing significantly to national economy. Lettuce leaves are usually consumed raw and without any restriction to daily intake. However, lettuce is characterized by its great ability to accumulate nitrate in leaves which can be harmful to human health. Thus, nitrate concentration in lettuce is considered one of the more important quality parameters (Cometti *et al.*, 2011).

Lettuce (Lactuca sativa) is one of the most important vegetables in human diet. The plant is full of vitamins and minerals with lots of fiber which facilitates colon peristalsis. Lettuce is 26th among 39 vegetables and fruits of nutrition value and is fourth of consumption. It‘s the most popular salad crop in the world and because of used crude, its vitaminsinter to human body without change. Iran ranks 9th country in the world for lettuce production and 11th for area culture (FAO, 2009).

Lettuce is full of vitamin A and minerals like Ca and Fe. It is mostly used as salad with other salad vegetables like tomato, carrot, cucumber and usually served alone or with other salad vegetables (Hasan *et al.*, 2017). Kaiser & Ernst (2016) Lettuce (Lactuca sativa) is one of the hydroponic vegetables most frequently cultivated. Hydroponics is plant growing technique without using soil. Plants can only be cultivated in a nutrient solution (liquid culture) or grow by an inert medium (culture of aggregates). In both systems, the irrigation water supplies all the nutritional needs of the crops (Kaiser & Ernst, 2016).

Reduction of light intensity represented the main environmental factor affecting lettuce quality indicators. However, although nitrate increase due to low light intensity was significant, nitrate accumulation in leaves remained within European Union’s permissible levels. Furthermore, a direct light-intensity effect on fresh weight and an indirect one on nutritional value (ascorbic acid) of lettuce were also evident (Kosma, 2013). During crop growth a number of factors may affect vegetable quality and quantity. Improving the growth factors is crop quality and quantity key. Thus growers need to increase their production by adopting appropriate strategies and techniques which will lead to sufficient and reliable yields without depleting the natural resource base.

Within the several techniques used in lettuce cultivation, the use of mulches is known to be worthwhile, being an important reason for the crop’s quality and productivity improvement (FontanettiVerdial *et al.*, 2001). Plant spacing is one the factors that can affect vegetable quality and quantity. Optimum plant density ensures the plants to grow uniformly and properly through efficient utilization of moisture, nutrients, light and thus causes to produce maximum yield of lettuce (Firoz *et al.* 2009). Greenhouse lettuce production is less expensive than field lettuce production with nearly 40 acres of greenhouse lettuce produced in the U.S. in 2013. High temperatures throughout the southeast limit conventional field production of lettuce. Due to technological advances in greenhouse production, producers in the southeast have more opportunities in the hydroponic lettuce market (Hickman, 2016).

Provide the best environment for the lettuce as possible, as our temperatures in the greenhouse were too high for optimal production levels of lettuce, but managed to produce decent heads. When all the factors are in balance, commercial lettuce production can be carried out successfully and the lettuce will be an easy sale, but when they become out of tune, quality and production may decline at a rapid pace, and the financial gain aspect of the operation may be circumvented (Mayall, 2010).

Conclusion

Due to the rapid urbanization there are problems of food and conventional methods using soil are not much effective to fulfill the demand. The researches indicates that alternative farming practices like hydroponic agriculture are more efficient for production of lettuce and other vegetables.

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