A SEMINAR PAPER

ON

GREENHOUSE FOR HYDROPONIC CULTIVATION OF STRAWBERRY

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Abstract

The term hydroponic refers to modern agricultural techniques that use nutrient solution rather than soil for crop production. As the population increases while total cultivable land is decreasing constantly meanwhile feeding humans is a great issue. A large number of plants and crops or vegetables can grow by all six types of hydroponic systems. Hydroponic is getting popular for a disease-free and eco-friendly system all over the world. Comparing experiment four hydroponic systems for strawberry (Fragaria x ananassa) production was carried out in a greenhouse tunnel and to assess what type of system is better for strawberry plants development and rich better yield and quality. The vertical with hydroponic pot system surpassed the other system in yield while the percentages of ^{o}brix are higher in the upper level of the systems. The vertical with three pipes had the highest percentage of low fruit quality. A comparison also made for hydroponic and soilless cultivation for strawberry where yield gap and survival rate are is higher in the hydroponic system. Though hydroponic is a technical and costly system, it would help the farmers in long run as a beneficial system.

Keywords: hydroponic types, strawberry production, yield gap, survival rate,

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Chapter I

INTRODUCTION

1.1 Background

Hydroponic has been recognized as a modern method of producing vegetables, fruits as well as ornamental crops such as herbs, roses, freesia, and foliage plants (Dunn,.2015). Hydroponic is a modern agriculture technique that uses nutrient solution rather than soil for crop production (Bridgewood,2013; Hochmuth and Hochmuth,2001a). Since the usage of methyl bromide has been banned in soil culture, the demand for hydroponic cultivation grown has rapidly increased in the last few years(Dunn.,2015).

Strawberry (Fragaria X ananassa) is a nutritional food and source of micronutrients such as minerals, vitamin C, folate, phenolic substances and also provides natural antioxidants and fat-soluble vitamins such as vitamin A and tocopherol and carotenoids such as lutein and zeaxanthin. It prevents inflammation, oxidative stress, cardiovascular disease (CVD), certain types of cancers, type 2 diabetes, obesity (Francesca et al., 2013). World strawberry production in 2011 was about 4.3 million tons of fresh fruit on an estimated 2.4 million hectares of land (FAO, 2011). Protected cropping under hydroponic greenhouses produces more yield than open-field farming. Strawberry is a short duration crop and gives high yield and having a higher market value, its cultivation is increasing (Jared Rubinstein., 2015). Rapid production of strawberry is needed to meet the increasing demand in our local market traders (Hossan et al., 2013). One of the biggest hurdles for indoor production is the high-water requirement and environment for strawberry cultivation, where greenhouse with hydroponic or aquaponic systems could be used to solve this problem (Jared Rubinstein., 2015). According to BBS (2011), the total cultivable of agricultural land from 1976-77 to 2010-11 is decreasing. On the other hand, pollution is increasing at a significant rate since feeding that huge pollution is a great issue. In the outdoor production system, there is always exists a huge loss due to insect attack, the use of excessive fertilizers & pesticides and irrigations, and also poor governance (Quddus et al.,2004). As the total cultivable land area is decreasing and food demand is increasing day by day, so cultivation in the greenhouse with the hydroponic technique could be used as a solution to overcome open field farming challenges, ensure food security, and to get more quality products. Hydroponic strawberry cultivation can increase total yields, enhance harvest efficiency, improve fruit quality by reducing the use of pesticides, and also provide protection against temperature and rainfall (Cantliffe et al., 2003). Specialized growing containers such as polyvinyl chloride (PVC) troughs that can be raised or lowered to a desirable height can not only accommodate higher plant densities and increase yields per unit area (Paranjpe et al., 2003) but also assist us by giving advantages such as ease of harvest and diminish the labor costs. Since strawberry is a short duration crop and its production schedules depend largely on the environment in which they are grown so to get good production from protected cultivation under a multistage hydroponic system needs good governance with real-time monitoring. Protective structures, such as high or low tunnels, greenhouses, or glasshouses, can protect the crop from rain, strong winds, and extreme temperatures. Protective structures with insect screens can reduce the entrance of insect pests and maintain pollinators (Powell et al., 2003).

Strawberries grown in the hydroponic systems need to be provided with all major and minor nutrients. Naturally, wind, bees, and other insects help in the pollination process of strawberry flowers. But in a greenhouse, the activity of these natural agents is restricted, so the use of commercially available bumblebees is important to ensure good pollination (Ashwin, 2003). In recent days, many new technical inputs have been poured by the scientific community regarding indoor strawberry cultivation. This study aims to review the accumulated knowledge of strawberry production, particularly in hydroponic systems.

1.2. Objectives:

The specific objectives of this review are:

- To explore the different types of hydroponic cultivation that can be associated with greenhouse.
- To explore the yield potential of strawberry under greenhouse hydroponic systems cultivation.
- To identify the yield gap, survival rate, soluble sugar of strawberry under the different hydroponic systems.

Chapter II

MATERIAL AND METHOD

This is a review paper on strawberry cultivation under greenhouse condition. All the data were collected from online and offline library resources. Books and journal articles available online from different sources i.e., Google Scholar, Web of science, ResearchGate were consulted. All the relevant information collected from these sources was rightly cited in this document.

Chapter III
FINDING OF THE REVIEW

Hydroponic systems are customized and modified according to the recycling and reuse of nutrient solutions and supporting media.

3.1 Types of hydroponic Techniques

There are commonly six basic types of hydroponic systems as they are wick, drip, ebb-flow, deep water culture, nutrient film techniques, and aeroponic. Though a hundred variations can be found among these basic types of hydroponic systems, all hydroponic systems are a variation or combination of these six. All are described below with an illustration.

3.1.1 Wick system

This is the simplest hydroponic system requiring no electricity, pump, and aceators (Dunn., 2013). Plants are placed in an absorbent medium like coco coir, vermiculite, perlite with a nylon wick running from plant roots into a reservoir of nutrient solution (Sharma et al., 2019). The nutrient solution is drawn into the growing medium from the reservoir through capillary action with the usage of two wicks. Since there are no moving parts in this system, it is considered a passive system to maintain rather than ebb and flow. This system works well for small plants, herbs, and spices but does not work for thirsty crops (Acharya et al., 2019). This is the only drawback of this system.

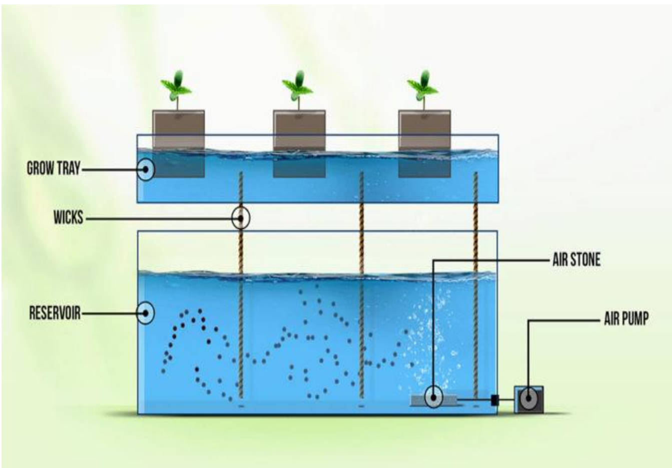

Fig1. Wick system of hydroponics.

3.1.2 Ebb and flow system

This is the first commercial hydroponic system that works based on the principle of flood and drain. Nutrient solution and water from reservoir flooded through a water pump with a timer to growing a bed until it reaches a certain level and stays there for a certain period so that it provides nutrients and moisture to plants (Sharma et al.,2019). The timer is set to come on several times a day, depending on the size, and type of plants, temperature, humidity, and type of growing medium (Dunn.,2013). Besides, it is possible to grow different kinds of crops but the problem of root rot, algae, mold is very common (Nielsen et al., 2006) hence a filter unit is required to modified some system.

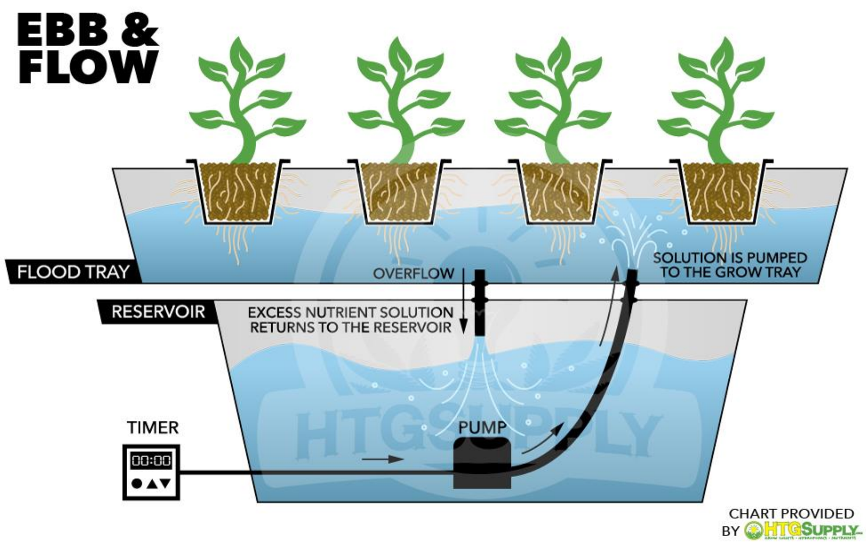

Fig2.Ebb and flow system.

3.1.3 Drip system

This hydroponic system is the most probably used most widely in home and commercial in the world (Dunn.,2013). Water and nutrient solution from the reservoir is provided to individual plant roots in appropriate proportion with the help of pump (Rouphel and Colla., 2005). Plants are usually placed in a moderately absorbent growing medium so that the nutrient solution drips slowly(Kumar et al., 2018). A lot of crops can be grown systematically with more water conservation.

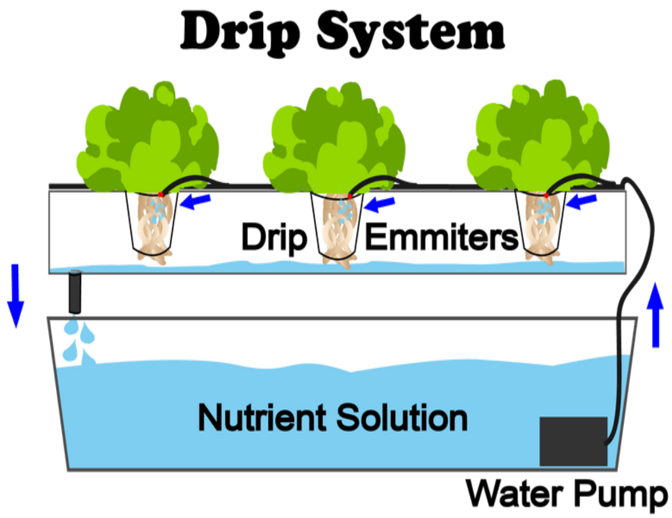

Fig3. Drip hydroponics system.

3.1.4 Deep water culture system

In deep water culture, roots of plants are suspended in nutrient-rich water and the air is provided directly to the root by an air stone (Sharma et al., 2018). The bucket system is a classical example of this system. Plant roots are suspended in the nutrient solution where they grow quickly. It is mandatory to monitor oxygen and nutrient concentration, salinity, and ph(Domingues et al., 2012). Larger fruit production plants like tomatoes, cucumber, strawberries are known well growing in this system.

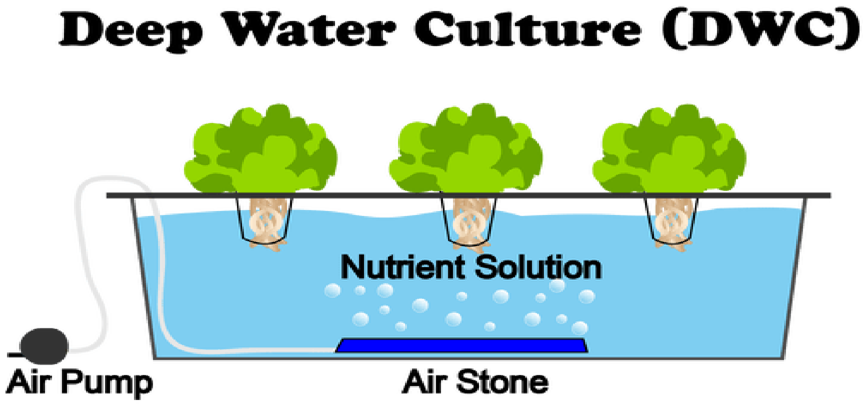

Fig4: Deep water hydroponic culture.

3.1.5 Nutrient film techniques (NFT)

In this system, water or nutrient solution circulates throughout the entire system; and enters grow tray via a water pump without a time controller (Domingues et al., 2012) hence a constant flow is maintained in this system. This system is slightly slanted sop that nutrient solution can run through roots and down back to the reservoir (Sharma et al., 2018). Fungal infection can be attacked to the roots because roots are always submerged to water. This system is worldwide famous for lettuce production.

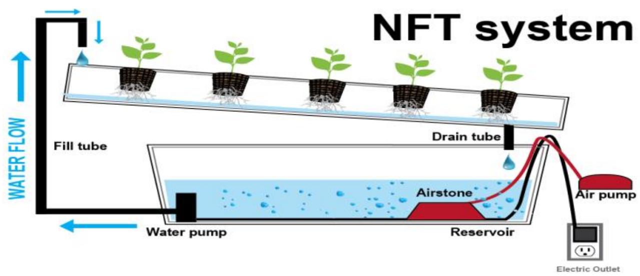

Fig5: Nutrient film system.

3.1.6 Aeroponic system

This system is considered the most high-tech type of hydroponic system. Air is primarily growing media like N.F.T. The roots hang in the air and are misted with nutrient solution (Dunn., 2013). An aeroponic system needs a short cycle timer that runs the pump for a few seconds every couple of minutes. This system is practiced in a protected structure. This system is quite suitable for leafy like lettuce, spinach (Research news, 2008).

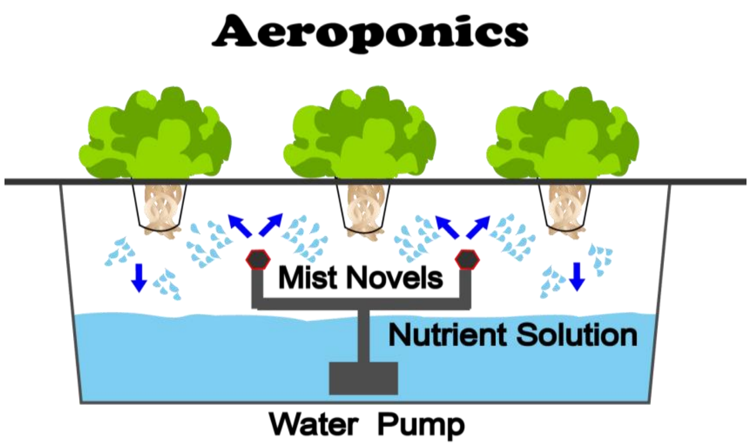

Fig6: Aeroponic system.

3.2 Nutrients for hydroponic greenhouse cultivation

Many studies conducted on crop nutrient requirements. Almost 17 elements are found for optimum plant growth. These elements can be divided into two groups such as macronutrient and micronutrient given and summarized below in table no.1.Supply of nutrient solution based on the parameter as pH (Resh 1993) and electrical conductivity. The optimum range of pH of nutrient solution for hydroponic cultivation is 5.8-6.5 and a good EC range is between 1.5-2.5 dS/m.

Table 1. Summary of nutrient for hydroponic crop growth (Ali et al., 2018)

Types of Nutrients	Nutrient Name	Function in plants
Macro	Nitrogen	Chlorophyll, amino acids, and proteins synthesis
	Phosphorus	Photosynthesis and growth
	Potassium	Enzyme activity
	Hydrogen	Water formation
	Carbon	Formation of organic compound
	Oxygen	Release energy for sugar
	Magnesium	Enzyme activity

	Sulfur	Formation of amino acids and proteins
	Calcium	Cell growth
Micro	Iron	Used in photosynthesis
	Cobalt	Nitration fixation
	Boron	Vital for reproduction
	Chlorine	Help root growth
	Copper	Enzyme activation
	Manganese	Component of chlorophyll
	Molybdenum	Nitration fixation
	Zinc	Component of enzymes

3.3 Crops for hydroponic greenhouse cultivation

Every crop need suitable a environment for its successful growth. The only condition to achieve a suitable environment for better crop production is the protected cultivated or hydroponic greenhouse cultivation (Khan et al., 2018). It is possible to grow cereals, vegetables, fruits, fodder, flowers, condiments, and medicinal plant in a hydroponic greenhouse (Singh and Singh,2012). The summary of those crops that are grown in the hydroponic greenhouse is shown below in table 2. According to Singh and Singh (2012), hydroponic greenhouse yield per area is more than open agriculture yield per area.The controlled environment and re-use of nutrients help to make a comparison of production.

Table 2. Summary of crops for hydroponic greenhouse cultivation (Singh and Singh.,2012; Das et al., 2012; Hayden, 2006).

Types of crops	Names of crops	
	Common Name	Botanical Name
Cereals	Maize	*Zea mays*
	Wheat	*Triticumaestivum*
	Oat	*Avena sativa*
	Soybean	*Glycine Max*
	Peas	*Pisumsativum*
Vegetables	Tomato	*Lycopersiconlycopersicum*
	Cucumber	*Cucumis sativus*
	Lettuce	*Latuca sativa*
	Chilli	*Capsicum frutescens*
	Cabbage	*Brassica oleracea var.*
	Cauliflower	*Brassica oleracea*
	Radish	*Raphanus sativus*
	Green bean	*Phaseolusvulgaries*
	Bell pepper	*Capsicum annum*
Fruits	Strawberry	*Frahariaananassa*
	Melons	*Cucumis bicolor*
Fodder crops	Sorghum	*Sorghum bicolor*
	Barley	*Hordeum vulgare*
	Carpet grass	*Axonopuscompressus*
	Alfalda	*Cynodondactylon*

Flower	Roses	*Rosa berberifolia*
	Marigold	*Tagetespatula*
	Carnations	*Dianthus caryophyllus*
	Chrysanthemum	*Chrysanthemum indicum*
Condiments	Oregano	*Origanum vulgare*
	Sweet basil	*Ocimumbasilicum*
	Parsley	*Petroselinumcrispum*
	Mint	*Menthaspicata*
Medicinal	Indian aloe	*Aloe vera*
	Celous	*Solenostemonscutellariodies*

3.4 Advantage of hydroponic greenhouse chamber

The hydroponic greenhouse system is facing many challenges, despite all challenges, this modern agricultural system is the most productive method for crop production (Khan et al., 2018). The hydroponic greenhouse system produced a higher nutritional value crop(Jones Jr,2012). The hydroponic greenhouse has more advantages than disadvantages (Banda-Guzman and Lopez-Salazar., 2014). Plants under this hydroponic greenhouse system never come under stress because water and nutrient always available to the plants (Ruth., 2009). The advantages are summarized in table 3.

Table 3. The summary of advantages of hydroponic greenhouse system (Khan et al., 2018)

SL No.	Advantages
1	The year-round crop is grown

2	Crops are protected from extreme weather conditions
3	No or little use of pesticides
4	Water efficiency is nearly about 90%
5	Sustainable urban growth
6	Reliable harvest
7	Reduce the environment pollution as no use of mechanical plow and other equipment so that reduce the burning of fossil fuel
8	Crop can be grown in cities where soil is not abundant

3.5Comparison of hydroponic systems in strawberry production

3.5.1 Cumulative yield

Ramírez Gómez et al.,(2012) conducted an experiment where all the high-density hydroponic systems evaluated were statistically different in comparison to individual bags(IB) system in cumulated yield (Tukey, $P\leq0.05$) (table 4). Vertical hydroponic system (VHS) surpasses other systems(Fig8) with 4595.30 g. The V4T system was the second that showed acceptable yield with 3961.40 g, V3T system showed 2755.30gm while BI showed the minimum yield of all is 856.00 g.

Fig7. Hydroponic systems (a) individual bags (b) Vertical with three pipes (c) Vertical with four pipes (d) Vertical with hydroponic pots.

3.5.2 ºBrix

According to Ramírez Gómez et al.,(2012) ºBrix of harvested fruits was higher (Tukey, $P \leq 0.05$) in the highest level of each hydroponic system (Table4). The comparison of means test (Tukey, $P \leq 0.05$) formed eight groups. V42, V43, V44 systems were the highest with an average of 9.73, 9.85, 9.94% of ºBrix (Fig.9). 10.63% of ºBrix was placed second with the V33 system. The best of all was VMH5 because the highest value of ºBrix is an average of 10.85%. Wang and Camp (2000) mentioned that the content of soluble sugar is affected by the maturity stage, genotype, geological origin, and the growth temperature. All levels of system exceed the index of quality of ºBrix according to Mitcham et al., (2002) with a minimum soluble solid content of 7ºBrix.

3.5.3 Size

Statistical significance (Tukey, $P \leq 0.05$) helps to find out different fruit sizes in different hydroponic systems in categories A and D in Table 4. Four statistical groups was formed to mean comparison testing (Table 5) The VMH3 system was placed in the second position with 48.70% of fruit category A, almost half of the harvested fruit of this system was large in size. The V41 recorded 57.49% of fruits of A category responding to the large fruit (>3.2 in diameter). About 60% of harvested fruits were in this category D (1.6-1.9 cm in diameter). The V33 system recorded the 24.05% of fruits in this category and it was the only in the group A that had the highest percentage of small fruits. The top system level recorded the highest percentage of the fruit of category D (Ramírez Gómez et al.,2012).

3.5.4 Quality grade

Significant differences were found in the third and first-class in the percentage of fruit quality (Table 4).The V41 system was the of all within the group a with 51.79% of the first quality (Table 5) where the V33 system had the lowest quality with 20.63%. Vigor, quality, and yield of species will be reduced when feeding on the sap of plant mentioned by Klamkowski et al., (2007)

Table 4. Statistical significance (Pr>F) of hydroponic system on cumulative yield, quality and size of strawberry fruit (Ramirez-Gomez et al., 2015)

SV	DF	CY	°Brix	Quality grades			Size			
				1st	2nd	3rd	A	B	C	D
B	2	.2543	0.0286	0.8943	0.0737	0.0687	0.0086	0.1147	0.0161	0.2480
Trt	3	<0.0004	<0.0001	0.0095	0.4158	0.0092	0.0026	0.0349	0.0765	0.0043
E	6									
T	11									

SV: Source of variation DF: Degrees of freedom B: Blocks Trt: Treatment

E: Error T: Total CY: Cumulative yield

Table5. Grouping of means by the method of Tukey ($P \leq 0.05$) of the percentage of the size of fruit in every level of hydroponic systems for strawberry production.

LIHS	Size							
	A	Tukey $P \leq 0.05$	B	Tukey $P \leq 0.05$	C	Tukey $P \leq 0.05$	D	Tukey $P \leq 0.05$
B1	30.52	abc	20.55	ns	39.49	ns	9.45	ab
V31	40.08	abc	36.51	ns	20.05	ns	3.36	b
V32	41.41	abc	26.07	ns	23.83	ns	8.68	ab
V33	19.15	bc	24.71	ns	32.09	ns	24.05	a
V41	57.50	a	26.30	ns	15.09	ns	1.11	b

V42	40.76	abc	38.88	ns	15.91	ns	4.44	b
V43	46.15	abc	33.35	ns	16.84	ns	3.66	b
V44	27.89	abc	24.23	ns	37.10	ns	10.78	ab
VMH1	`16.83	c	42.70	ns	34.06	ns	6.41	b
VMH2	35.96	abc	29.13	ns	32.72	ns	2.19	b
VMH3	48.70	ab	34.80	ns	13.90	ns	2,.60	b
VMH4	25.25	bc	43.31	ns	29.20	ns	2.24	b
VMH5	35.92	abc	33.78	ns	21.61	ns	8.68	ab

Means with different letters are statistically different (Tukey, $P \leq 0.05$)

LIHS: level inside the hydroponic systems ; ns: not significant.

Table 6. Grouping of means by the method of Tukey ($P \leq 0.05$) of the percentage of the fruit quality in every level of hydroponic systems for strawberry production.

LIHS	Quality					
	1st	Tukey $P \leq 0.05$	2nd	Tukey $P \leq 0.05$	3rd	Tukey $P \leq 0.05$
BI	37.17	Abc	39.85	Ns	22.97	b
V31	37.72	Abc	37.72	NS	24.56	ab
V32	37.96	Abc	34.26	Ns	27.78	ab
V33	20.63	C	27.46	Ns	51.90	a
V41	51.79	A	27.21	Ns	21.00	b
V42	40.00	Abc	44.17	Ns	15.83	b
V43	47.70	Ab	31.24	Ns	21.06	b
V44	32.05	Abc	26.93	Ns	41.03	ab
VMH1	`26.55	Bc	39.25	Ns	34.20	ab
VMH2	39.83	Abc	40.87	Ns	19.30	b
VMH3	36.21	Abc	35.36	Ns	28.43	ab
VMH4	29.70	abc	41.62	Ns	28.68	ab
VMH5	36.61	abc	33.89	Ns	29.50	ab

Means with different letters are statistically different (Tukay, P≤ 0.05).

LIHS: level inside the hydroponic systems

ns: not significant.

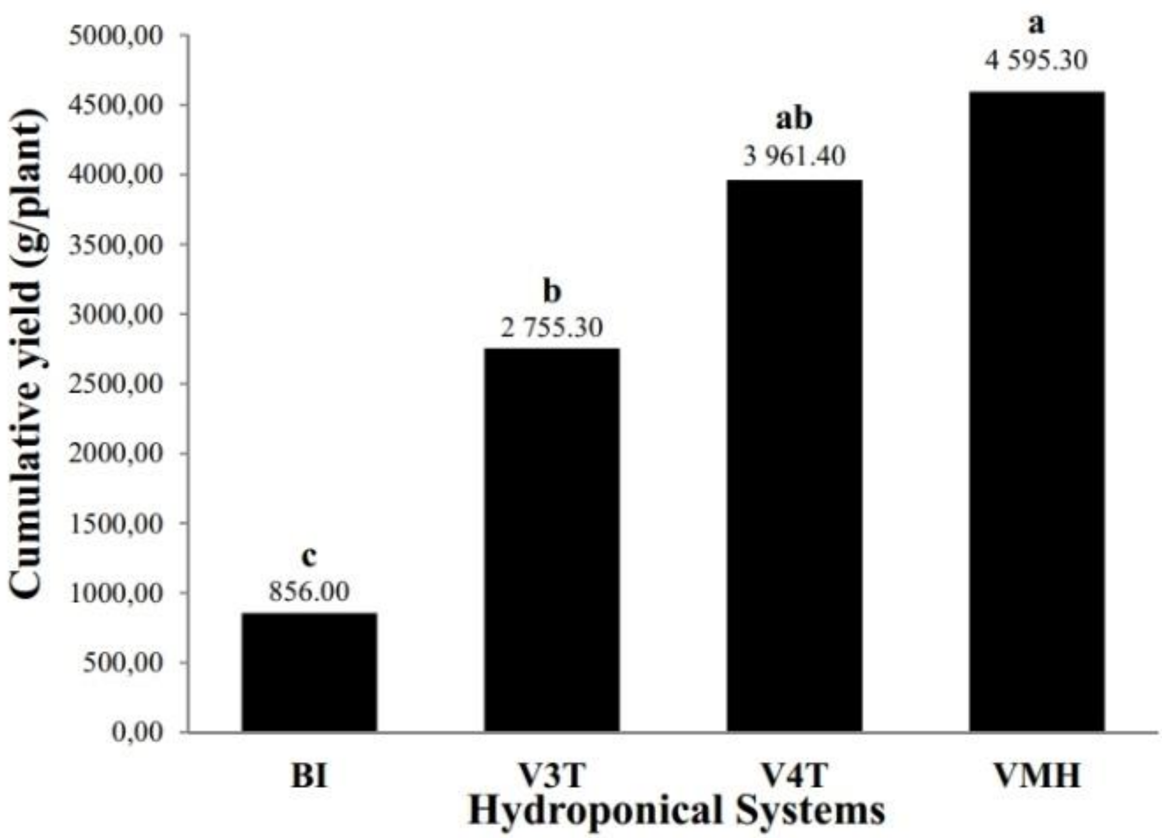

Fig8. The cumulative yield of hydroponic systems for strawberry productions.

Means with the different letters are statistically different (Tukey*P*≤ 0.5) BI: Individual bags, V3T: Vertical with three pipes, V4T: Vertical with four pipes, VMH: Vertical with hydroponic pipe.

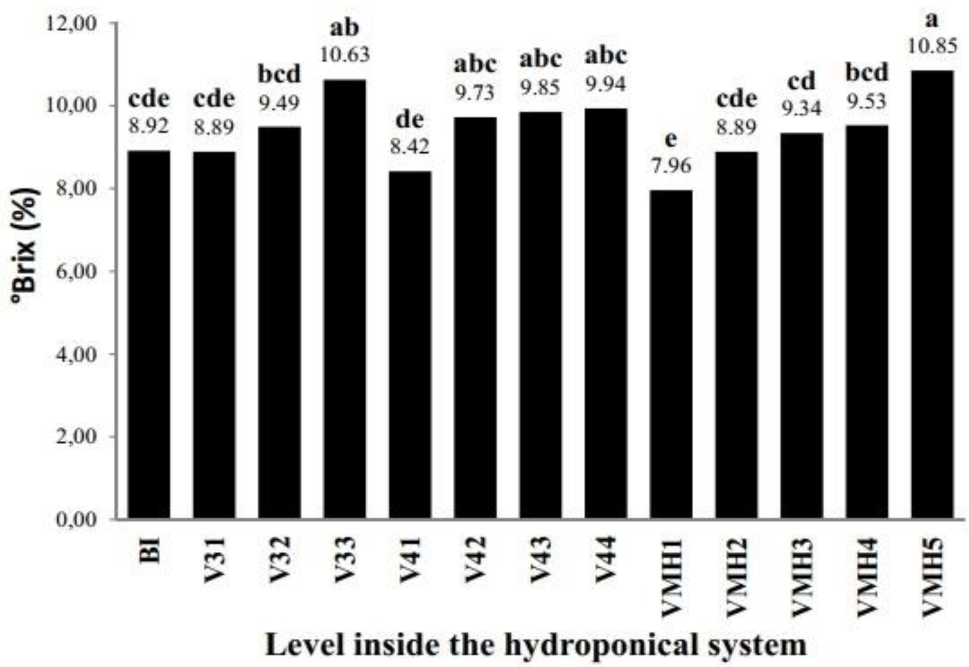

Fig9. ºBrix at each level inside of hydroponic systems for strawberry production.

Means with the different letters are statistically different (Tukey, $P \leq 0.005$). Abbreviation for

BI: Individual bags V31: Vertical with three pipes, level one V32: Vertical with three pipes, level 2 V33: Vertical with three pipes, three one V41: Vertical with four pipes, level one V42: Vertical with four pipes, level two V43: Vertical with four pipes, level three V44: Vertical with four pipes, level four VMH1: Vertical with hydroponic pot, level one VMH2: Vertical with hydroponic pot, level two VMH3:

Vertical with hydroponic pot, level three VMH4: Vertical with hydroponic pot, level four VMH5: Vertical with hydroponic pot, level five.

3.5.5 Strawberry yield and weight

According to the experiment of Treftz and Omaye (2015), the total yield of soil-grown strawberry 70. The hydroponic strawberry had a 17% higher yield compared to soil-grown strawberries. In August at the beginning of harvesting hydroponic strawberry had a mean weight of 6.2 g/strawberry and decreased to 4.1 g/strawberry in March at the end of the season. Meanwhile, for soil-grown strawberries, it decreases from 9.9 g/strawberry to 3.1 g/strawberry. All strawberries are grown in conventionally and hydroponically, but the standard deviation was large which indicates a wide variation in weight in all strawberries. But the standard deviation is comparatively small in hydroponic strawberries. Since the optimum growing condition is being provided in hydroponic strawberries, those plants will face less stress and stress is an important factor because it helps to increase the fruit size.

Table5. Yields and mean mass of hydroponic and soil strawberries (Treftz and Omaye,2015)

Types	Total yield	Mean mass± SD	t	P
Soil-grown strawberries	70	7.1± 3.7	3.03	0.0028
Hydroponic strawberries	85	5.4± 3.0		

3.5.6 Survival rate of plants

Hydroponic plants had a survival rate of 80% where the soil-grown plants had only 50%. Although all plants including hydroponic and soil-grown got their identical integrated pest management treatments, the soil plants are subjected to more insect attacked especially aphids and spider mites and fungus guts. Since hydroponic is a closed system, pest did not thrive in the hydroponic condition. With the higher plant survival rate, the hydroponic system could save money in the long run**.** So the ultimate result of Treftz and Omaye,(2015)study is using a hydroponic system on a large scale has the potential to reduce pesticide usage. This could be accomplished by the farmer with higher economic benefits in the long run though the initial cost of hydroponic is quite high compared to the soil-grown system.

Table 6. One year plant survival rate

Types	Starting plant	Plants surviving 1 year	% survival rate
Soil-grown strawberries	30	14	46%
Hydroponic strawberries	30	24	80%

3.6 Drawbacks of hydroponic greenhouse

Though hydroponic is an advanced level technique it has some significant limitations. Sonneveld (2000) said that technical knowledge and the higher initial cost is required for commercial-scale cultivation and controlled environment. Expert management skill is necessary to ensure optimum plant growth condition. Constant supervision is needed if the system is not automated. Without proper management, there is a chance of direct and indirect introduction of water and soil-borne microorganism (Islam et al., 2016). The full production might be lost if there arise any problem. Finally, it needs to supply light and energy to run the system (Van os, 2002).

Chapter IV

CONCLUSIONS

- There are six types of hydroponic systems such as wick, water, ebb and flow, nutrient film techniques (N.F.T.), drip, and aeroponic systems. Literature review suggested that all these systems can be associated with cultivation. Each of the systems is specialized with different kinds of vegetables, fruits, fodders, ornamentals crops.
- Several studies reported the comparison in size, mass, ^{o}Brix, nutritional quality among four hydroponic systems, and the vertical with hydroponic pots system gave a higher result in yield , the vertical with three pipes gave the lowest fruit quality of strawberry.
- Different studies revealed the yield difference between the hydroponic systems with the traditional cultivation of strawberry to evaluate the effective one. Though hydroponic system had a high installation cost, less maintenance cost, less infectious product, year-round crop cultivation would help to make hydroponics as beneficial in long run.

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