Int. J. Agr. Ext. 03 (03) 2015. 195-200

Available Online at ESci Journals

International Journal of Agricultural Extension

ISSN: 2311-6110 (Online), 2311-8547 (Print)

http://www.escijournals.net/IJAE

COMPARISION BETWEEN HYDROPONIC AND SOIL SYSTEMS FOR GROWING STRAWBERRIES IN A GREENHOUSE

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A B S T R A C T

Consumption of strawberries has been asserted to have many health promoting bioactive compounds including antioxidants. Growing fruits and vegetables hydroponically represent a possible opportunity towards sustainable crop production; it would be beneficial to examine the feasibility and the potential ability to replace soil systems for growing strawberries. Unlike leafy greens, the root structures, stalk, and fruit are more complex and require more physical support. In this study, hydroponic strawberries were higher in terms of fruit yield and plant survival rate. In soil-grown strawberries, the overall mass was significantly higher by 23%, but there was a larger variation of fruit size indicated by a large standard deviation. Startup costs for growing strawberries in hydroponic systems can be more than soil systems. Growing strawberries in hydroponic systems are feasible, at reasonable cost and more sustainable compared to traditionally soil grown systems. Future research should investigate various hydroponic growing methods and the feasibility of growing at the commercial level.

Keywords: Hydroponic, greenhouse, strawberry, feasibility, technology.

INTRODUCTION

Hydroponic food production, or growing food without soil, is increasing worldwide ad seem to have a positive overtone as consumers are becoming more aware of the environmental benefits (Jensen, 1999). Hydroponics can be grown in arid or urban conditions regardless of soil quality, making hydroponics advantageous for growing food closer to the consumer (Bellows *et al*., 2003). The hydroponic system has several advantages such as; conserving water, allowing for year-round production, increasing yields, and minimizing use of pesticides (Resh & Howard, 2012). Additionally, hydroponic fruits and vegetables have been documented in the literature as having higher nutritional value and more desirable sensory attributes compared to soil grown produce (Buchanan & Omaye, 2013; Gichuhi, *et al*., 2009; Selma *et al*., 2012; Sgherri *et al*., 2010).

The majority of previous hydroponic research has focused on leafy greens, peppers and tomato fruit (Arias *et al*., 2000; Buchanan & Omaye, 2013; Gruda, 2009; Koyama *et al*., 2013). However, research evidence regarding hydroponic strawberry production under hydroponic systems has been seen as scanty. Strawberries are nutritious fruits containing high antioxidant concentration and health promoting bioactive compounds. The consumption of strawberries is associated with several health benefits including: lowering of cholesterol, improvement of vascular endothelial function and anti-inflammatory biomarkers, and reduction of oxidative stress mediated diseases such as cancer (Giampieri *et al*., 2012; Hannum, 2004; Meyers *et al*., Zhang *et al*., 2008). Therefore, growing strawberries hydroponically would have several health advantages to the consumer and be environmentally resourceful, i.e., less water and pesticide consumption.

There are some limitations for comparing soil and hydroponic growing systems because they are fundamentally different; however, the most reliable way for comparison is to place both systems under optimal growing conditions (Gruda, 2009). The goal of this one-year study was to observe the feasibility of growing

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strawberries as measured by; the differences in yields, monthly distributions of fruit production, and plant survival rates in hydroponic conditions compared to conventionally soil-grown strawberries. We compared the differences between start-up costs, maintenance costs, and upkeep time between the two systems.

METHODOLOGY

Hydroponic and soil plants were grown and maintained at the University of Nevada, Reno (UNR) Agricultural Experimental Station Greenhouse Complex. The Agricultural Experimental Station Greenhouse Complex is a state of the art facility, equipped with automatic heating and cooling systems. No supplemental light was used for either system due to the 340 days of sunlight that Northern Nevada experiences per year. The greenhouse temperature was maintained at 70°F during the day (5:30 AM to 6:30 PM) and 60°F (6:31 PM to 5:29 AM) at night with relative humidity averaging at 30%. Sixty bare-root, ever-bearing strawberry plants ('Ozark Beauty,' Fragaria x ananassa) were purchased from Stark Brothers Nurseries & Orchard Company (Louisiana, MO). Thirty strawberries were planted in hydroponic conditions and thirty strawberries were planted in soil conditions. The soil plants and the hydroponics plants were randomized and placed in eight rows on two tables, as outlined in Figure 1. Both the hydroponic and the soil-grown plants were numbered for recording and monitoring plant health. In both growing conditions, first-buds and runners were manually removed to increase fruit production.

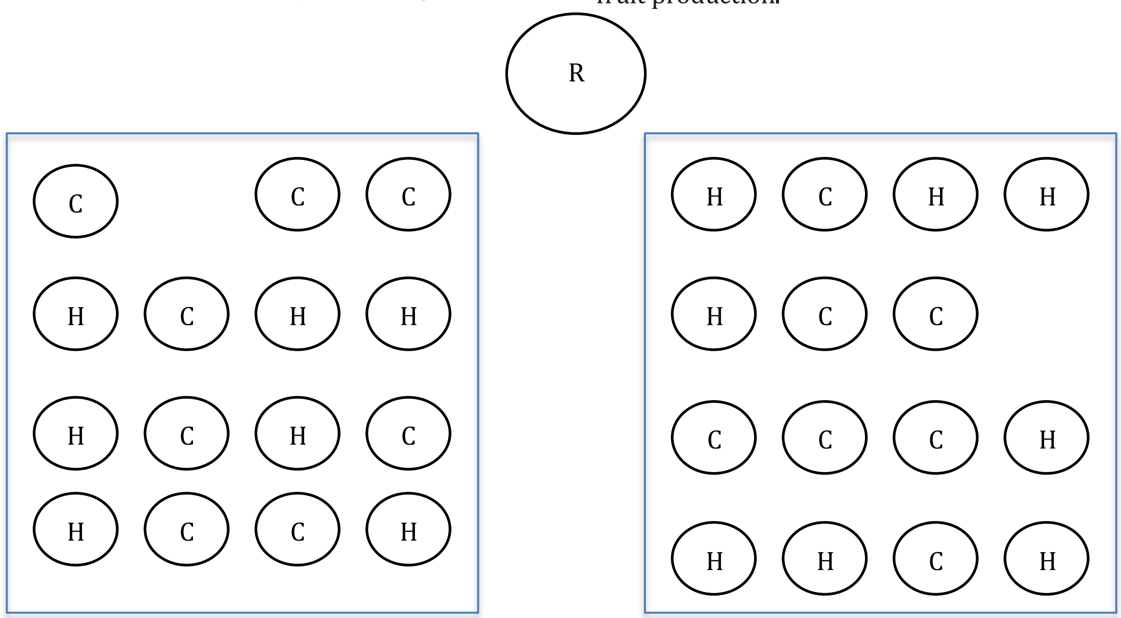

Figure 1. Design for experimental treatments. Schematic illustrates the randomization of the hydroponic (H) and soil-grown (C) growing conditions. Water reservoir is indicated by 'R'.

Soil system: The Ozark Beauty strawberries were planted according to manufacturing instructions, in 3-gallon black plastic nursery pots with drainage holes in the bottom of the pots. Two strawberries were planted in each pot, approximately 10" apart. The soil was a mixture of 1:1 ratio of Miracle-Gro potting soil (Marysville, OH) and Nevada topsoil. The pH of the soil was monitored using a portable pH meter before planting and during the season (Oakton Instruments, Vernon Hills, IL). The pH of the soil was typically between 5.5-5.7. The plants were watered using a drip-irrigation system for 15 minutes three times a week. The plants were fertilized with Miracle-Gro all-purpose fertilizer (Marysville, OH) every six weeks.

Hydroponic system: The hydroponic strawberry systems were grown in recirculating hydroponic bucket systems. A series of 15 buckets were constructed. Orange, five-gallon paint buckets were purchased from a local hardware store and spray-painted black to decrease light transmission that may promote algae growth within the system. Fifteen 8-inch net pots were purchased from the local hydroponics store, along with pearlite used as the growing medium (Reno, NV). The bare-root strawberries were planted in the pearlite according to the instructions provided by the nursery. Hydroponic plants can generally be planted closer together compared to soil grown plants (Resh & Howard, 2012); for this reason, two strawberries were planted in each 8-inch net. The roots were fanned out with the crown at the line of the pearlite. The Waterfarm® system was used to deliver water from the bucket to the plants by utilizing a pumping column and drip ring (Reno, NV).

The plants were aerated using an all-purpose hydroponics pump (Active Aqua AAPA 15L, Reno, NV). The systems were aerated 23 hours a day. One hour per day, the system was stopped to decrease algae growth that is produced with continuous water movement. The pH of the plants was maintained between 6.0 – 6.4 and adjusted, if necessary, three times a week. The nutrient solution used was a commercial General Hydroponics Flora series solution (Sebastopol, CA). During initial stages of growth, the nutrients were added in a 1:1:1 ratio. The macronutrient concentration of nitrogen, phosphorus and potassium was 22:36:31 ppm/L. During the early bloom phase, the nutrients were added in a 3:1:5 ratio; during the late bloom phase, the nutrients were added in a 1:0:2 ratio. The average ppm of the plants was 400 ppm, adjusted three times weekly if necessary. This is considerably lower than manufacturer instructions; however, previously reported literature indicated that a lower nutrient solution concentration does not affect plant growth (Ferguson, Saliga III, & Omaye, 2014). Every four weeks, the systems were cleaned by spraying off any algae buildup in or around the buckets or media, and the nutrient solutions were replaced.

Pest maintenance: In the UNR greenhouse, aphids and spider mites infected the plants. Spider mites, when present, were sprayed with PyGanic®(MGK, Minneapolis, MN) bimonthly. Fungas gnats were present in both soil and hydroponic plants because they feed off of algae and plant roots. The gnats were effectively controlled by yellow sticky whitefly trap (Seabright Laboratories, Emeryville, CA) placed around and above the tables. Aphids were treated first by physical methods of integrated pest management. However, more aggressive approaches were necessary; thus, one teaspoon of dish soap was mixed with one liter of water and sprayed on the plants with the aphid infection once per month. The solution was allowed to sit on the plants for 30 minutes, and then thoroughly rinsed with water.

Statistical analysis: Statistical analysis was conducted with Graph Pad Prism Version 6.0f. The independent t-test was used to determine differences in berry mass, with a significance level set a $p<0.05$. Results are expressed as mean ± standard deviation (SD).

RESULTS AND DISCUSSION

Fixed and variable cost comparisons: The fixed and variable costs for the hydroponic plants compared to the soil-grown plants are outlined in Table 1 and Table 2. The hydroponic system has a higher startup cost compared to the soil system. It is important to note that the hydroponic system would last through multiple seasons without the need to replace the soil. The soil for the soil system would eventually have to be replaced, fertilized and other efficient management practices, such as crop rotation, would need to be considered. These are factors that could be avoided with hydroponic farming. The soil system had a lower cost, but used 30% more water compared to the hydroponic system. Another important factor to consider when choosing a growing system is labor costs. Soil-grown produce is more often cited for having increased labor costs because of weeding, watering, and spraying of pesticides (Resh & Howard, 2012). With our system, we found the soil strawberries to have increased weeds compared to hydroponic strawberries. However, the hydroponic system overall was more labor intensive because of the time required to check and monitor the pH and ppm of the solutions. Additionally, each month it took about 1.5 hours to change and replace the nutrient solutions in the hydroponic buckets; the soil strawberries did not necessitate extra monthly maintenance routines.

Economic models have been developed to estimate profitability associated with hydroponic lettuce, and it has been modified to fit different scenarios (Coolong, 2012; Donnell *et al.*, 2011). When considering hydroponic food production on a commercial scale, developing an economic model to determine cost-benefit analysis for optimum economic feasibility would aid both the commercial and small-scale farmer. A decade ago, it was assumed hydroponic lettuce and tomatoes would be the only crops to be economically feasible for hydroponic food production (Jensen, 2013); however, since then, food prices have more than doubled and the economic revenue for different crops should be investigated for the commercial and small scale farmer (Jensen, 2013).

Strawberry yields and weights: The strawberry yields and weights are outlined in Table 3, and shown in Figure 2. The total yield of the soil-grown strawberries was 70 strawberries.

Table 1. Fixed and Variable Costs for Hydroponic Grown Strawberries.

Fixed Costs			
Item	N	Price	Sub Total
5-gallon paint bucket	15	$2.97	$44.55
Hydroton	50 L bag	$87.00	$87.00
pH and ppm meter	2	$55.00	$110.00
8-inch netting	15	2.25	$33.75
Drip ring	15	5.95	$89.25
Pumping column	15	5.95	$89.25
Air pump	4	$20	$80
Electric cords and power strips	MISC	$60	$60
Total	-	-	$593.80
Variable costs			
Item	N	Price	Sub Total
Nutrientsa	2 liters	$4.20/liter	$8.40
pH adjuster	0.1/liter	$8.20/liter	$0.82
Bare root plants	30	$11.99/25 plants	$14.39
Electricityb	201.48 kWh	$0.118/kWh	$23.77
Waterc	360 gallons	-	-
Heat	Unknown	-	-
Total	-	-	$47.38

[a]Amount estimated from General Hydroponic Nutrients, Flora series

bEnergy cost was estimated by the following equation Cost($/day) = E(kWh/day) × Cost(cent/kWh), where E= .552 kWh/day (4 air pumps operating at 6 watts/air pump) and Cost= Northern Nevada is about $0.118 kWh/hour. Electricity was estimated at 24 watts (6 watts/air pump) operating at 23 hours/day for a total energy usage of 0.552 kWh/day. 0.552 kwH/day x 365 days/year x $0.118 kWh = $23.77.

[c]Water was calculated by adding 2 gallons/bucket x 15 buckets, replacing water 12 times yearly.

Table 2. Fixed and Variable Costs for Soil Grown Strawberries.

Fixed Costs			
Item	N	Price	Sub Total
3-gallon buckets	15	$1.91	$28.65
Potting soil	2/2.5 cubic feet	$13.97	$27.94
Plumbing	MISC	MISC	$125.00
Water reservoir	1	$20	$20
Water pump	1	$69.00	$69.00
Electric cords and power strips	MISC	$20	$20
Total			$270.59
Variable costs			
Item	N	Price	Sub Total
Fertilizera	1 pound	$5.98	$5.98
Bare root plants	30	$11.99/25 plants	$14.39
Electricityb	0.93 kWh	$0.118/kWh	$0.11
Waterc	520 gallons	-	-
Heat	Unknown	-	-
Total			$20.48

[a]All-purpose Miracle Gro fertilizer was used, once every 6 weeks.

[b]Energy cost was estimated by the following equation: Cost($/day) = E(kWh/day) × Cost(cent/kWh), where E= 0.018 kWh/week, and Cost= Northern Nevada is about $0.118 kWh/hour. Electricity was estimated at 24 watts operating at 0.75 hours/week for a total energy usage of 0.018 kWh/weeks x 52 weeks/year x $0.118 kWh = $0.11.

[c]Water was estimated by visual inspection of water level of from the 25 gallon reservoir, approximately 10 gallons/week.

The hydroponic strawberries had a 17% higher yield compared to the soil grown strawberries. The distributions of the monthly weights from the strawberries are shown in Figure 3. In general, the average weight of the strawberries was at its highest at the beginning of the harvesting season and decreased as the season progressed, with its lowest point being at the end of the season.

In August, hydroponic strawberries had a mean weight of 6.2 g/strawberry and decreased to 4.1 g/strawberry in March. The same trend was seen in soil-grown strawberries, with a mean mass of 9.9 g/strawberry in August decreasing to 3.1 g/strawberry in March. Strawberry weights were significantly higher in those soil-grown, with a mean mass of 7.1 g/strawberry compared to 5.4 g/strawberry in those hydroponically grown. In the totality of strawberries grown both conventionally and hydroponically, the standard deviation was large, indicating a wide variation of weights in all harvested strawberries; however, standard deviation in weight was smaller comparatively between hydroponic strawberries (3.0 vs. 3.7) and soil-grown strawberries.

Hydroponically grown plants are thought to have increased yields because of the precise control over the nutrient solution and the ability for them to be in their optimum growing conditions. Stress may be an important factor for hydroponic strawberry production since it increases fruit size. Hydroponic plants are generally less stressed than soil-grown plants since the plants are in their optimum growing conditions all the time. Further research, such as investigating stress factors, should be conducted to discover the variables in hydroponic strawberry production that may yield larger fruit sizes.

Table 3. Yields and Mean Mass of Hydroponic and Soil Strawberries.

	Total yield (n)	Mean mass (g) ± SD	t	p
Soil-grown Strawberries	70	7.1 ± 3.7	3.03	0.0028
Hydroponic Strawberries	85	5.4 ± 3.0		

Plant survival: Plant survival rates for both growing conditions are shown in Table 4. Hydroponic plants had a higher survival rate at 80% compared to the soil-grown strawberries, which survived less than 50%. Lower soil-grown plant survival rates are attributed to increased pest issues with the strawberries grown in soil compared to the hydroponic. Although both growing systems received identical integrated pest management treatments, the soil plants suffered more and the pests thrived in the soil-grown strawberries, especially the aphids and spider mites. This can be attributed to increased beneficial bacteria and microbes that pests thrive on in soil conditions (Resh & Howard, 2012). Although the pests did affect some of the hydroponic plants, the pests did not thrive in the hydroponic conditions. With the higher plant survival rate, the hydroponic system could save money in the long run since our study showed hydroponics are more resistant to aphids, spider mites and fungus gnats. Pest infections are a large source of economic losses for farmers, and research for best pest management methods for hydroponic food production is warranted. Pesticide usage is a concern for many consumers – buyers are health and environmentally conscious regarding pesticide usage.

The results found in this study suggest that using hydroponic systems on a large scale has the potential to reduce pesticide usage. Accomplishing this would provide the farmer with higher economic benefits.

Table 4. One-year plant survival rate.

	Starting plants (N)	Plants surviving 1 year (N)	% survival rate
Soil-grown Strawberries	30	14	46%
Hydroponic Strawberries	30	24	80%

CONCLUSION AND RECOMMENDATIONS

Although hydroponic food production seems to have a positive overtone because of the numerous environmental benefits, it is important to consider the obstacles that small scale and commercial farmer may encounter. The initial higher investment may be a barrier for the adaptation of hydroponic food production for business owners. Further research should investigate economic and crop yields feasibility – determining these factors can provide resources to farmers interested in hydroponic food production. Agricultural extensions can play a key role in the adaption of hydroponic growing methods by providing evidence-based educational tools in a clear language to farmers without a formal education. Agricultural extension can also play a vital role in educating business owners on the economic and environmental benefits of growing hydroponically.

Although hydroponic strawberries seem to be a relatively feasible option to grow in otherwise non-farmable land, other factors can influence the quality of the produce and should be considered for further research. The hydroponic farmer has vast choices when growing, such as media, different system types and nutrient solutions. Our method was chosen for the simplicity of design and relatively low costs compared to a large, custom-built system. However, other designs with perhaps one reservoir could potentially lower labor, saving time and money. In addition to researching multiple growing systems in hydroponic strawberry production, future research should also compare the nutritional composition and sensory attributes of the strawberries for each system.

Acknowledgements: We thank Eric Horton for technical and maintenance assistance. We acknowledge the Nevada Agricultural Experiment Station, University of Nevada, Reno for the support of this study. HATCH #0745. The research was done and reported to partially fulfill dissertation requirement of C. Treftz.

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