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RESEARCH PAPER

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The interaction on the horticultural characteristics of economically important vegetables in simple nutrient addition production (SNAP) hydroponics and conventional production system

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Abstract

The study was conducted to evaluate the performance of different vegetables grown in SNAP hydroponics and conventional production system. SNAP hydroponics production system the simple nutrient addition program. In this system any container with cover can be used as long as it can contain approximately 2 liters of solution. The benefits that can be derived from growing crops under this system include higher yields in a small space, environmental protection; efficient recycling of water and nutrients, healthier plants and faster crop maturity. Among of the four vegetables grown sweet pepper and lettuce performed well under the SNAP hydroponics system. The plants were taller, produced more leaves, matured earlier and had higher yield compared to those grown under the conventional production system. Both the broccoli and tomato did not perform well in SNAP hydroponics and conventional production system. Broccoli was succumbed by the attack of pest (*Helecoverpa armegera*) while tomato was lodged due to strong winds.

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Introduction

Vegetables contribute a large portion of the nutrients needed by the body for proper nutrition. They are good sources of Vitamins C, A, and B complex, iron, and fair sources of minerals. Among the nutritional and economically important vegetable crops are lettuce, sweet pepper, tomato and broccoli.

Lettuce (*Lactuca sativa* Linn.) which belongs to Compositae family is one of the most expensive vegetables grown in the Philippines. It is used as fresh vegetable, or as ingredient of food preparation such as salads and sandwiches for its unique taste and crunchy texture. It is cool weather crop and produces best at 15 to 18˚C although some varieties have been produced to adapt to warmer conditions. It is available all year round and is at its peak from June to December.

Tomato (*Lycopersicon esculentum* Mill) and sweet pepper (*Capsicum annum*) belong to Solanaceae or night shade family. They are used as fresh vegetable or as ingredient of many delicacies and food preparation such as vegetable salads and other food items. Tomato is used as raw material in various food processing industries such as soups, pastes, catsups, sauces, pickles and many products. Sweet pepper is also used as raw material for processed products and medicine. They can be grown in relatively warmer climates. However, best yield can be obtained when grown in well-distributed rainfall and mean temperature from 18 to 27 ˚C at blossom-setting time (Bautista and Mabesa, 1977).

Broccoli (*Brassica oleracea var. italica*) belongs to Brassicaceae family. It is distinguished by its tender heads that are tightly packed with immature flowers known as “ curds” formed by shortened flower parts.

In Philippines, lettuce, tomato, sweet pepper and broccoli, are usually field-grown. However, in other countries, these vegetables are also being grown commercially using hydroponics. It was not so long ago that the word “hydroponics” raised thought of future technologies to feed the world. Today, hydroponics refers to a family of techniques, which is, and has been, in use throughout the world to meet specialized agricultural needs. No longer a future technology, but a current methodology, hydroponics farming is having an impact upon both farmers and consumers (http://www.hydroponicsbc.com/trends.html).

Hydroponics, often as the cultivation of plants in water, has gained popularity as technique for growing of crops. It was introduced in the 1930s but only confined in laboratories to facilitate plant growth and development. After World War II, Japan had the largest installation of hydroponics system for commercial production.

Growers all over the world are using hydroponic techniques on a small scale to grow fresh vegetables year-round in small spaces, such as an apartment balcony. Greenhouses and nurseries are used in growing plants in a soilless, peat-or bark –based growing mix. The nutrients are applied to growing mix through the water supply. Therefore it is also a type of hydroponics (http:www.growingedge.com/community/archive/view.php3?c=IN).

In the Philippines, the technology on SNAP hydroponics has been developed and has shown good potential for use because of its simplicity (Santos and Ocampo, 2002) SNAP means simple nutrient addition program. This is simple and easy technology for growing plants in nutrient solution with or without the use of inert medium to provide mechanical support. This was found to have good potential for adoption in crowded areas particularly in urban and coastal areas where suitable area for growing is not available. It is intensive, uses fertilizer and water efficiently, needs small land spaces, and protected with the environment. With this technology, plant roots need not search out or compete for nutrients in the soil, and plants are healthier and reach maturity faster. This technology can also be used in areas where the climate is unpredictable and protected cultivation is necessary. The use of protective structures with plastic sheet roofing to protect plants from heavy rain and too high temperature is seen as a potential farming technique that would allow higher production of different kinds of vegetables under hydroponics production system.

This study was conducted to evaluate the performance of different vegetables grown in SNAP hydroponics and conventional production system.

Materials and methods

Growth and yield performance of different vegetables under snap hydroponics and conventional production system

Lettuce head type (var. President), sweet pepper (Hybrid Bless), Tomato (New Kingkong) and broccoli (Prominence) were used in the study.

Seeds of crisp head lettuce, sweet pepper, tomato and broccoli, were sown separately in seed boxes filled with heat sterilized mixture of garden soil, compost and protect the seedlings from rain and direct sunlight. The seedling was picked by transferring healthy individual seedling to prepared propagation cells upon reaching the true-leaf stage. A starter solution of one-tablespoon urea (45-0-0) dissolved in one gallon of water was applied to the seedlings 3 days after germination. The seedlings were hardened 5 days before transplanting. This was done by gradual exposure of the seedling to sunlight and withdrawal of water until they s how signs of temporary wilting.

Experimental design and treatment

The experimental was laid out in a simple Randomized Complete Block Design (RCBD) with three replications. The variable used was method of growing that consisted of the following;

H_0= Conventional (Container gardening)

H_1=SNAP Hydroponics

Each vegetable was treated as a separate experiment. Polyethylene plastic pots filled with garden soil were used to contain plants under the conventional production system while styropor fruit boxes were used for the SNAP production system. The experimental set-up was done under protective structures. Three existing tunnel-type structures with UV-stabilized plastic roofing were used. The polyethylene plastic pots and empty styropor bos of fruits were arranged at a distance of 50 cm × 50 cm.

Two styropor boxes were used per type of vegetable depending on the number of plant. Same number of plant was used in conventional method of growing as in SNAP hydroponics system. Alleyways of 1 meter between treatments and replications were provided to facilitate farm management as well as data gathering.

Set-up of SNAP hydroponics system (Santos and Ocampo, 2002)

Preparation of solution container

The empty stryropor fruit boxes were used to hold approximately 2 liters of nutrients solution. These were lined with .005-mm polyethylene plastic. Holes (2-3 cm diameter) were provided in the cover of stryropor box in order to have ventilation. Additional bigger holes were made to hold the styropor cups where the vegetable seedling was grown.

Preparation of the cups with the seedling

The styropor cups (6 ounces) were used to contain the vegetable seedling. Holes were provided at the bottom of the cups and a screen net was placed to cover the holes. The styropor cups were then half-filled with coco coir dust.

Growing the plants

The bottom of the cups was always immersed in the solution especially if the roots have not developed extensively yet. Upon development of the roots, the solution was maintained 2-4 cm between the bottom of the cup and top of the solution.

Standard planting steps are adopted for the vegetable (lettuce). The remaining three vegetables (broccoli, tomato and sweet pepper) followed the same steps of planting.

Nutrient delivery system

Hoaglands solution was as a source of macro and micronutrients until flowering. From then on commercially available hydroponics fertilizers (Hydroponic Nutrient produced by Manutec Garden Care Products) was used until crop maturity. About 9 liters of the solution were presented then poured into the styropor fruit boxes. Replenishment of four liters solution was done every two weeks. Solution pH was monitored every week.

Conventional cultivation system

The sizes of polyethylene plastic containers that were used under conventional system were 7×7×16 inches for lettuce; and 9x9x16 inches for the other three vegetables. There was only one plant per container. The polyethylene bags were filled with garden soil medium up to 3.5 cm. below the mouth. Equal volume/amount of medium was placed per bags per crop. The following fertilizer rates were applied for each crop;

A. Lettuce – 120-60-60 kg N,P_2O_5,K_2o/ha
B. Broccoli – 120-90-90 kg N,P_2O_5,K_2o/ha
C. Tomato - 90-120-90- kg N,P_2O_5,K_2o/ha
D. Sweet pepper – 90-120-90 kg N,P_2O_5,K_2o/ha

The amount of fertilizer that was applied per pot was based on the amount that each plant is supposed to receive in the field given the recommended fertilizer rate and population density per hectare. All fertilizer materials were mixed with the soil before planting.

Transplanting

The seedlings were transplanted either to the styropor box or in the polyethylene plastic container depending upon the treatment. There were 4 lettuce plants, and two broccoli, sweet pepper and tomato plants per styropor fruit box.

Harvesting

Lettuce was harvested when almost all the heads in the set-up were formed. This was done by cutting the base of the plants with a sharp knife. For sweetpepper , green mature fruits were harvested by handpicking twice a week. For tomato, harvesting was done twice a week at the breaker stage as indicated by color streaks on the fruits and for broccoli, when curds attain marketable size harvesting by hand was done.

1. These were sorted and classified into marketable and non-marketable fruits. Marketable fruits were those that met the following criteria;
2. Tomato – not damaged by insects or diseases, not deformed ad with at least 4 cm equatorial diameter;
3. Sweet pepper – at least 4 cm long and 2 cm wide, free from diseases, insects and mechanical damage;
4. Lettuce – free from diseases, insects and mechanical damage;
5. Broccoli – curd is compact and free from disease, insects and mechanical damage.

Non-marketable fruits, which did not meet the criteria for marketability

Horticultural characteristics

Plant survival, plant height, number of leaves, days to maturity of lettuce, number of days from transplanting until 85% of the plants in each treatment had flowered, number of days from transplanting to first harvest of sweet pepper, tomato and lettuce, root weight inside and outside the styropor cup were gathered.

Results and Discussion

Horticultural characteristics

Percent plant survival

The percent plant survival of the four vegetables (tomato, sweet pepper, broccoli and lettuce) was significantly influenced by the method of production system (Table 1) although all four vegetables grown in hydroponics system had 100% survival one week after transplanting, while those grown under conventional production system exhibited slightly lower plat survival. It is probable that the balanced and readily available nutrients in hydroponics made the plants resistant to environmental stresses at the early stage ensuring a 100% survival. Ikeda (2000) observed in his study on celery and horneworths that the management of nutrient solution and formulation is a great importance to attain higher plant survival and yield in non-circulating hydroponics.

Table 1. Percent plant survival of four vegetables grown in conventional and SNAP hydroponics production system

Vegetables	Production system		CV (%)
	SNAP hydroponics	Conventional	
Sweet pepper	100.00	96.00	9.53
Tomato	100.00	83.33	11.45
Broccoli	100.00	83.33	11.13
Lettuce	100.00	90.67	3.43

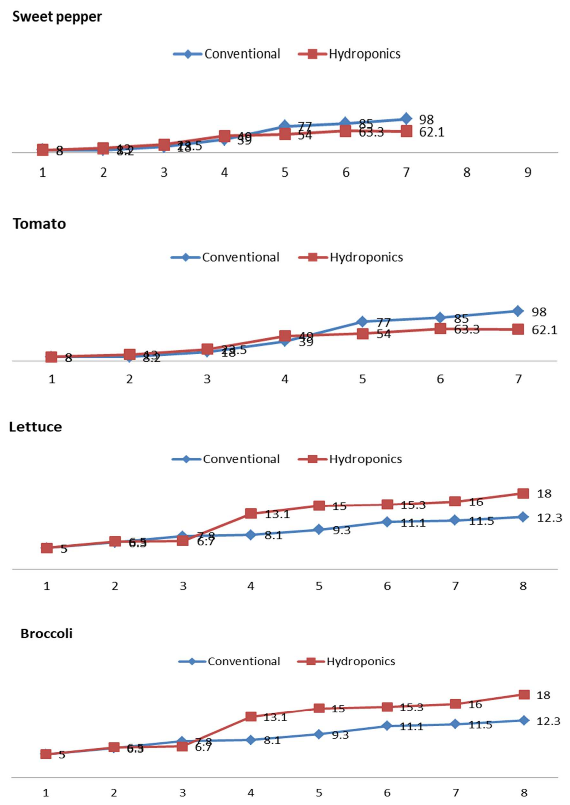

Fig. 1. Plant height of lettuce, broccoli, sweet pepper and tomato under conventional and hydroponics production system

Plant height

During the first two weeks after transplanting, the plant height of sweet pepper was the same in both conventional and hydroponics production system (Fig. 1). Later, the plant inn hydroponics was significantly taller until they reached maturity except on the 5th and 7th week. In lettuce, the hydroponically grown ones were also significantly taller than those grown in the soil at the later growth rates stages. Mohyuddin and Younnus (1999) stated that there is uniform absorption of nutrients available in hydroponics solution. This may have made the plant grow faster while in conventional system the nutrient is not easily absorbed by the roots due to soil fixation, compaction and other factors making a slow growth on plants. In tomato no significant differences in plant height were also observed in both production systems during the first weeks after planting. Later, however, the plants under the conventional production system significantly surpassed the plant height of plant grown in hydroponics. The slow increase in hydroponically grown tomato was due to wilting causing the plant to senesce earlier. The volume of nutrient solution may be too small for the tomato plant which inherently accumulates heavier biomass than sweet pepper and thus demand more water and nutrients. Production system did not significantly affect the plant height of broccoli, during its earlier growth (1st and 2nd week) as well as in the later stages except on the 3rd and 4th week when those grown in hydroponics system were taller than those under conventional system. However, broccoli plants grown in both systems were affected with *Helicoverpa armegera* that cause a slowing down of their growth.

Number of leaves

Generally, there are an increasing number of leaves during the time of experimentation (Fig. 2), although at the later stages the number of leaves decreased in all vegetables except lettuce. This was brought about by the senescing leaves which fall as the plants reached maturity. The number of leaves of sweet pepper showed similar trend with plant height. The hydroponically grown plants significantly had more leaves, starting at 3rd week to 9th week (Fig. 2). At the earlier stage (1st-2nd week), the plants under both systems did not differ significantly in the number of leaves. In lettuce, the number of leaves from transplanting was also not affected by the production system (Fig. 2). Significant increase in the number of leaves on the 2nd week was observed. As discussed earlier, this was brought about by then readily available nutrients to the plants. Also, the slow increase in number of leaves in the conventional system was due to the wilting and falling of some leaves.

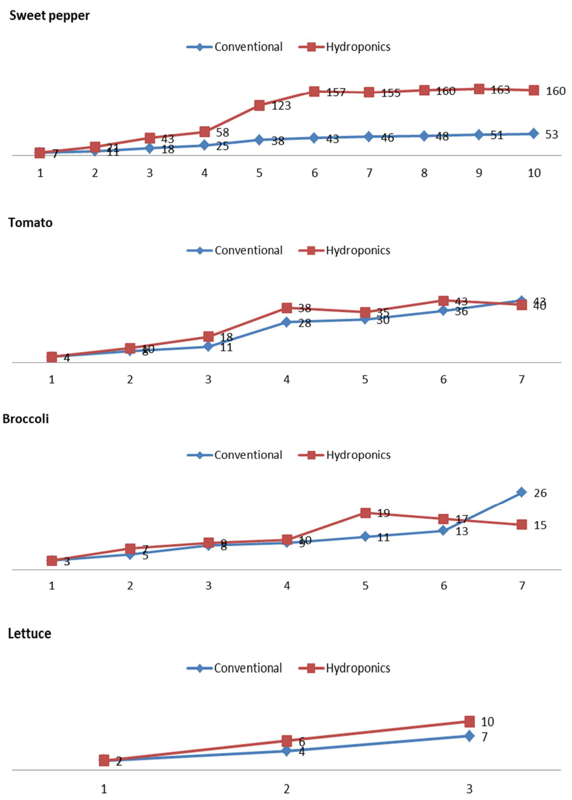

Fig. 2. Average weekly number of leaves of sweet pepper, tomato, broccoli and lettuce under SNAP hydroponics and conventional production system

Differences in the number of leaves of tomato in both systems were shown only in the 4th to 6th week. The hydroponically grown plants and more leaves than in conventional production system (Fig. 2) indicating faster growth and development of the crop. However, at 7th week the number of leaves in the hydroponically grown plants decreased relative to those grown in conventional system. As pointed earlier, the tomato plants were inherently big and the volume of nutrient solution used may no longer suffice to sustain optimum growth and development of the plant. Broccoli under both systems at earlier had similar number of leaves (Fig. 2). As plants grew, from the 2nd to 5th week there were more leaves developed in hydroponically grown plants than in conventional production system. However, at the later stage (6th week) no differences in both systems were observed. On the 7th week, plants under conventional system continued to increase the number of leaves significantly in contrast to a decreasing number of leaves in hydroponically grown plants starting in 5th weeks. The latter plants succumbed to the attack of *Helecoverpa armegera* even if the plants were sprayed with soap-hot pepper mixture. In addition, this insect also attacked the plants under conventional production system later that led to death of some plants.

Days from transplanting to flowering and crop maturity of sweet pepper, tomato and lettuce

The production system significantly affected the number of days from transplanting to flowering and to first harvest in sweet pepper. Those grown in hydroponics system were harvested earlier than those conventional production systems (Table 2). Lettuce grown in hydroponics also matured earlier at 32 days after transplanting as compared to those under conventional production system which matured four days later (Table 2). Resh (1989) also observed that plants matured faster under soilless culture system than in soil culture given adequate light conditions. Furthermore, the roots of the plants grown in hydroponics do not need to grow long and look for nutrients because the nutrient solution brings all the necessary nutrients directly to the plant. Due to these differences, plants grow much faster in hydroponics garden than in soil garden (http://www/ahl_hydroponics.com/:.html) and thus reach maturity faster. Similarly, Tadashi (2000) found that cucumbers and sweet pepper bear fruit earlier and more in hydroponics. Furthermore, Imai (2000) added that hydroponically grown vegetables such as Japanese welsh and vegetable soybean performed well in non-recirculating hydroponics.

Table 2. Number of days from transplanting to flowering and first harvest of sweet pepper, tomato and lettuce grown in SNAP hydroponics and conventional production system

Vegetables	Production System	Days to	
		Flowering	First Harvest
Sweet pepper	Conventional	29.33b	34.33a
	Hydroponics	16.00a	26.33b
CV (%)		1.94	11.13
Tomato	Conventional	19.33	33.33b
	Hydroponics	13.33	23.67a
CV(%)		11.80	11.13
Lettuce	Conventional	-	36.00a
	Hydroponics	-	32.00b
CV (%)		-	0.00

Table 3. Root weight (g) and length of lettuce, broccoli and tomato grown in SNAP hydroponics and conventional production system

Vegetable	Root inside the cup	Root Outside the cup		Total root
	Weight (g)	Length(cm)	Weight (g)	Weight
Lettuce	8.00	10.00	1.86	9.86
Broccoli	6.00	13.50	2.45	8.45
Tomato	18.00	23.00	5.20	23.20

Root yield of lettuce, tomato and broccoli

Table 3 shows the root weight of the three crops within and outside the styropor cups, as well as root length outside the cup. Root development concentrated within rather than outside the cup. This may be because the aggregate was also observed that the root weight and length both inside and outside the cup of hydroponically grown tomato was more voluminous and longer compared to lettuce for their growth. The small aggregate volume in the cup may have limited the proliferation of more roots. This may explain the finding that tomato did not satisfactorily perform well under the SNAP hydroponics production system, unlike sweet pepper and lettuce. Resh, 1989 reported that the main factors influencing the growth and distribution of root system are genetic differences in species and cultivars and soil factors. Local concentration of nutrients and size of the pots can also have significant effect on roots.

Table 4. Fruit size (cm) of sweet pepper and tomato grown in SNAP Hydroponics and conventional production system

Vegetables	Production System	Fruit size	
		Length	Diameter
Sweet pepper	Conventional	8.80	3.54
	Hydroponics	7.95	4.45
CV (%)		4.47	8.76
Tomato	Conventional	5.83a	4.63a
	Hydroponics	3.66b	3.14b
CV (%)		7.05	12.26

Yield and yield Components

Sweet pepper

Production system did not significantly influence the fruit size of sweet pepper (Table 4), but affected the number and weight of marketable and non-marketable fruits as well as total yield of the crop (Table 5 & 6). The hydroponically grown sweet pepper was found to be more superior in the aforementioned parameters compared to those under conventional system. Sweet pepper under this system had 50% heavier fruits compared to conventional production system and thus had higher yield per plant. This is due to the balanced plant food dissolved directly into the water so that the plants received perfect nutrition at all times (http://www.hydroponics.com/jack/index/html), as earlier discussed.

Table 5. Number of fruits/plant of sweet pepper and tomato grown in SNAP Hdroponics and conventional production system

Vegetable	Production system	Number of Fruits/plant		
		Marketable	Non-marketable	Total
Sweet pepper	Conventional	23.42b	6.50b	29.92b
	Hydroponics	54.33a	10.58a	64.91a
CV (%)		5.93	13.50	13.50
Tomato	Conventional	17.50a	6.33a	23.83a
	Hydroponics	8.33b	2.58b	10.91b
CV (%)		32.52	24.12	17.66

Tomato

Production systems significantly affected the fruit size of tomato (Table 4) number and weight of marketable and non-marketable fruits as well as the total yield (Table 5 and 6). Conventional production system significantly produced more fruits in contrast to hydroponically grown plants. Hydroponically grown plants were destroyed by strong winds that caused some plants to lodge which have probably affected photosynthate accumulation, resulting to poor development of fruits. More plants under the hydroponics system lodged due to poor plant anchorage unlike those grown in the soil. Moreover, unsatisfactory results on tomato fruit yield were observed in this experiment. Aside from lodging, higher temperature during the experiment may have contributed to the overall poor performance of tomato in both production systems. The average day temperature range during the month of November and December is 24.5-33.4^{o}C to 24.0-30.1^{o}C respectively (http://www.inq7.net/wea/2003). Divinigracia (1971) reported that tomatoes thrive best in average temperature range from 24-29°C during the day and from 15-20^{o}C during the night.

Table 6. Weight (kg) of fruits of sweet pepper and tomato grown in SNAP Hydroponics and conventional production system

Vegetable	Production System	Fruit yield (Kg/plant)			
		Marketable	Non-marketable	Total	Herbage yield (kg/plant)
Sweet pepper	Conventional	0.29b	0.05b	0.34b	0.45
	Hydroponics	0.70a	0.13a	0.83a	0.75
CV (%)		7.16	7.63	6.33	20.41
Tomato	Conventional	0.54a	0.26a	0.80a	0.59
	Hydroponics	0.01b	0.02b	0.03b	0.49
CV (%)		30.98	13.12	18.59	28.83
Broccoli	Conventional	-	-	-	0.64
	Hydroponics	-	-	-	0.68
CV (%)		-	-	-	17.75

An article on Hydroponics Culture of Tomato (http:///www.hydrogarden.com/gardens/food/tomato/htm) suggested that tomatoes are best grown at daytime temperature of 25°C and night temperature of 18oC. Although the problem is solved with the use of heat tolerant varieties, these are inadequate under extreme conditions (AVDRC, 1990). Divinigracia (1971) further reported that with high temperature and high relative humidity plants tend to develop more foliage and fewer as a result of excessive flower drops. He added that this condition also favors growth more disease. Villareal (1980) stated that tomatoes planted earlier or after September suffer from poor fruit setting, bacterial wilt and leaf disease.

Table 7. Head size (cm) and number of marketable and non-marketable heads of lettuce grown in SNAP Hydroponics and conventional production system

Production System	Head size (cm)		Number of heads/treatment	
	Polar	Equatorial	Marketable	Non-marketable
Conventional	3.56b	2.46b	4.33b	3.67b
Hydroponics	6.42a	5.71a	7.33a	0.67a
CV (%)	10.37	2.69	12.12	32.67

Lettuce

Hydroponically grown lettuce had bigger heads compared to those under the conventional production system (Table 7). Production system had significantly affected in terms of number of marketable heads formed, with hydroponically grown plants producing more heads. Resh (1989) stated that soil culture broadcast large quantities of fertilizers over the soil, in non-uniform distribution of plants, where large amount leached past plant root zone of 50-80%, thus there is inefficiency in fertilizer use. Soilless culture, on the other hand, uses small quantities of fertilizers.

Table 8. Weight (kg/plant) of marketable and non-marketable heads and herbage yield of lettuce grown in SNAP Hydroponics and conventional production system

Vegetable	Head yield (kg/plant)		Herbage Yield (kg/plant)
	Marketable	Non-marketable	
Conventional	0.15b	0.06	0.19a
Hydroponics	0.29a	0.01	0.07b
CV (%)	16.37	62.31	14.74

Hydroponically grown lettuce had higher marketable yield and herbage yield compared to conventional production system (Table 8). This agrees with Jensen and Collin (2011) who also found that head formation of lettuce is favored by low temperature and produces better yield and matures earlier with uniform nutrient taken up by the plants.

Conclusion

Under the condition of this study the SNAP hydroponics enhanced some horticultural and yield parameters of lettuce and sweet pepper such as percent survival, number of days from transplanting to flowering and harvest, weekly plant height and number of leaves, total fruit yield and total head yield relative to conventional production system. SNAP hydroponics system did not work well with tomato and broccoli.

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