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Fish molasses as indigenous nutrient source in the growth and yield of economically important vegetables in simple nutrient addition program (SNAP) hydroponics system

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Abstract

Simple Nutrient Addition Production (SNAP) hydroponics production system in this system any container with cover can be used as long as it can contain approximately 2 liters of solution. This study was conducted to evaluate the performance of economically important vegetables grown in SNAP hydroponics and conventional production system. The experimental was laid out in a simple Randomized Complete Block Design (RCBD) with three replications. The variable used was method of growing that consists of conventional (Container gardening) and SNAP hydroponics using fish molasses. 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

In tropical countries like Philippines, field cultivation of most vegetables provides a major source of income and fresh food for small-scale growers. Four of economically important vegetables in the country are tomato, sweet pepper, broccoli and lettuce. Sweet pepper offer considerable economic returns for farmers in tropical regions especially when grown during wet season. However, yield and sweet pepper varies according to the cultural management and environmental condition. Lettuce is widely grown throughout the temperature and subtropical region of the world and is used predominantly as fresh green in human diet (Ryder, 1986). It can also be grown in the Philippines especially in Mountain Province and some highlands in Mindanao (Sison, 2002).

Hydroponics, often defined as the cultivation of plants in water, has gained popularity as a technique for growing crops. It was introduced in the 1930s but only confined In laboratories to facilities 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-based growing mix. The nutrients are then applied to growing mix through the water supply. Hydroponics offers many advantages for commercial agriculture. Cultivating plants without soil eliminates the need for vast farmland and allows crops to be produced in greenhouse or even in desert sands. Hydroponics techniques also allow for the precise water and nutrient application directly to the root of each plant. Water is reused in these systems and less is lost through evaporation and run-off (htt://www.growingedge.com).

An alternative to the conventional field production system is hydroponics. Hydroponics came from the Greek words “hydro” meaning water, and “ponos” meaning labor, i.e. working water (Jones, 1983). It is a method of growing plants in a water and nutrient rich solution, without soil (Wattapreechanon, 2000; Jensen, 1990; Schimkat, 2002; Schwarz, 1995; and Hedeo, 2002).

In recent years, this technique has become of commercial interest for plant production. Widely used as research technique has become of commercial interest for plant production. Widely used as research technique, the soilless culture of plants was popularized in the 1930s (Diaz, 1998). According to Resh (1989), hydroponics can be dated back to the 1600s. However, plants were grown in soilless culture far earlier than this. Many believed that it started in an ancient city of Babylon with its famous hanging gardens, and was probably one of the first successful attempts to grow plant hydroponically. Ancient Egyptian hieroglytic records dating back to several years BC describe the growing of plants in water along Nile River without soil. Before the time Aristotle, Theopartus (327-287) undertook various experiments in crop nutrition, while Dioscorides dated back to first century AD.

In the following years researches developed many diverse formula for the study of plant nutrition, and these formulas are still being used in laboratory research in plant nutrition and physiology today. Between 1925 and 1935, extensive development took place in modifying the laboratory techniques of “nutrieculture” to large-scale production. In 1936, raising plants in nutrient solution was restricted in laboratories, where it is used to facilitate the study of plant growth and development. After World War II, Japan had the largest installation of hydroponics system, built by army, because their soil was contaminated and they could not grow their crops in other way. Hydroponics became popular again, not only in Japan and in the United State but also throughout the world. In the Philippines, hydroponics was introduced few years ago.

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Hydroponics makes it possible to grow plants in location where it would not normally be possible, e.g.g poor soil, rocky areas, and even balconies. With the use of artificial light it is even possible to successfully garden in a spare room or garage. Less labor is required than growing in soil because no digging or weeding is required. Nutrients and moisture are fully accessible in a hydroponics system, since plants need not compete for nutrients; more can be grown in smaller area. The increased control over controlled conditions makes it easier to provide best possible for plants. Leading to better quality produce and higher yield (htt://www. ext.vt.edu /pubs/environhort/42-084.html). Other advantages are: hydroponically grown vegetables can be pesticide-free through biological pest control; nutrient solution maybe re-used in other areas such as potted plants and turf management; growing media can be re-used and recycled; more intensive cropping techniques require less space and control over environmental factors to nutritionally superior, vegetable product (http://www.hydroponics.com /jack/index.html). Jensen (1990) added that plants root in soil by nature and rainwater to the plants. Scientists found that plant could be grown in different inert substrates or even water alone, provided that proper nutrients are available. In order to ensure the continous production of vegetables under hydroponics system (Mckowiak *et al.*, 1996). In actual cultivation, soilless culture offers culture offers earlier growth and higher yield (Ikeda, (2000). It involves no work using such spades and hoes, and machines such as tractors and no injury cost by continuous cropping.

Hydroponically grown plants are known to be more nutritious and taste good (Bradley, 2000. He added that that any plant could be grown hydroponically although in practice, hydroponic gardening is usually reserved for exotic plants and flowers, or as for greenhouse style vegetables, such as lettuce, tomatoes, peppers, cucumbers, melons and culinary herbs.

Tadashi (2000) pointed out that hydroponics is regarded as one of the most advanced growing techniques not only in terms of environmental protection but also for labor savings in this country. Since plant growth in hydroponics is generally faster than that in the conventional soil culture, more intensive and successive cropping is carried out. Hartman *et al.* (1997) stated that conventional container method of growing plants faces a number of problems. Hence, SNAP hydroponics using low-cost available empty styropor fruit box or other suitable containers, offer the possibility of resolving the problems (Santos and Ocampo, 2002).

The large increase on yield under hydroponics culture over that of soil may be due to several factors (Resh, 1989). In some cases the soil may be exceptionally poor, therefore soilless culture would be very beneficial. The presence of pest or disease in the soil greatly reduces overall production. Resh also reported some advantage of soilless culture versus soil culture. For plant nutrition, the soil reaction or pH is difficult to sample, test and adjust. On the other hand, plant nutrients for soilless culture are completely controlled, relatively stable, and readily available in sufficient quantities. It has a good control of pH, easily tested, sampled and adjusted. Plant spacing for soil culture is limited by soil nutrition and available light, while plant spacing for soilless culture is limited only by available light, therefore closer spacing is possible. Thus, it has increased number of plants per unit area. Weeds are present in soil culture, thus cultivation is needed, whereas there are no weeds for soilless culture 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 quantity of fertilizers.

Overall, the main advantages of hydroponics over soil culture are: more efficient nutrient regulation, availability in regions of the world having non-arable lands, efficient use of water and fertilizers, ease and low cost of sterilization of the medium, and higher density planting leading to increased yields per hectare (Gericke, 1999).

The uptake of nutrients by the plant ought to be in balance with the needs of the plant. It is clear that there exists a strong relation between needs and the growth rate of the plant. However, during the various stages of plant growth there can be different need for uptake elements. In Japan, Tachibana (1987) worked with cucumber and found that the absorption of nutrients was more severely inhibited by low root temperature than that of water. He added that several experiments showed that low root temperature inhibited the uptake of nutrients and water. According to van Winden (1988), precise nutrient added is a major advantage. He stated that lettuce grower would not use a "bloom" formula since fruiting and flowering need not be prompted. Hurd *et al.* (1995) added that nutrient solutions for tomatoes contain potassium sulfate in both the "grow" and "bloom" formulas, providing almost twice the sulfur content formulas for lettuce and cucumbers. Cucumbers use nearly twice calcium nitrate than tomatoes and lettuce during vegetative growth stage, but the same amount for tomatoes. With the aforementioned claims, the culture of vegetables in hydroponics showed a great potential in the market today.

Materials and methods

Experimental Design and Treatments

A 2x2 factorial experiment in Randomized Complete Block Design (RCBD) with three replications per treatment was used. Nutrient source was considered as Factor A and volume of aggregates as Factor B. Each vegetable was treated as a separate experiment. The treatments were as follows:

Factor A Fertilizer Sources

H_o- Commercial Hydroponics Solution (CHS)

H_1- ½ Commercial Hydroponics Solution (CHS)+Hydroponics Fish-Molasses Mixture (FHM)

Factor B Volume of Aggregates

V_o- 6 oz styropor cup

V_1- 9 oz styropor cup

The commercial hydroponics fertilizer was procured from an Agricultural Supply store. A 1-year-old fish entrails-molasses mixture at the ratio of 1:1 was used as organic fertilizer. The fish entrails and molasses mixture had been kept in sealed container to allow anaerobic decomposition.

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.

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. The nutrient composition of Hoaglands and Hydroponic Nutrient Solution are presented in Appendix Table 2. 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.

Tissue N, P, K contents (%)

Nitrogen, phosphorous and potassium contents of the leaf of lettuce and sweet pepper were determined using the Micro kjeldahl method, for nitrogen; phosphorous, vanbamolybdate method; and potassium, by the use of atomic absorption flamephotometer (PCARR, 1980).

N, P and K uptake (mg/plant)

Nutrient uptake was determined by getting the product of the total dry weight of plant multiplied by their respective N, P and K content.

Data and Plant Tissue Analysis

Data on horticultural characteristics, yield parameters of sweet pepper, and lettuce were analyzed following the analysis of variance for 2x2 factorial in experiment. Plant tissue analysis was done in the Plant Analysis Laboratory of the Department of Agronomy and Soil Science (DASS) for N, P and in Philrootcrop Analytical Laboratory for the analysis of K Content of the plant.

Production Cost and Return

The cost of production (e.g. fertilizers, chemicals, labor, etc.) was determined by recording all the expenses incurred during the implementation of the experiment. Returns were calculated by multiplying the total yield of the crop with the current price per kilo of the produce. The net income was determined by subtracting the total expenses from the total returns. Data were based on 480 styropor boxes, which can be contained in one-tunnel-type structure

Results and discussion

Horticultural Characteristics

Percent plant survival, root length and weight of lettuce and sweet pepper

Results showed that nutrient source did not significantly affect the percent of lettuce, but affected that of sweet pepper. Total root weight as well as root weight outside and inside the cup also significantly varied with the nutrient sources. Lettuce and sweet pepper grown in CHS had higher root weight outside and inside the cup compared to those grown in FHM. This could be attributed to improved plant growth of the said treatments and increased available supply of nutrient in hydroponics solution. Volume of aggregates significantly affected the plant survival of as well as root length, total root weight and root weight both inside and outside the styropor cup in both lettuce and sweet pepper. Lettuce grown in 9 oz styropor cup had higher plant survival. These plants also had heavier and longer roots within the cup while those lettuce grown in 6 oz styropor cup had longer roots outside. Marschner, (1995) pointed out that in terms of plant function (supply of nutrient, water and phytohormones) the size of the root system and also the root dry weight required for these functions mainly depend on the concentration of nutrient solution, and the physical, chemical and microbiological conditions in the substrates for root activity and formation of new roots.

Days to maturity of Lettuce

The number of days to head maturity of lettuce was significantly affected by nutrient source. Lettuce grown in CHS were the earliest to mature. This means that all the essential nutrients needed by lettuce were supplied at the right amount by CHS. In contrast the plant fed wit HFM were harvested one day later. Although the HFM had high N content (12.5%), it was probable that not all of these may be available to plant directly since lettuce is a short-term crop. Organic fertilizers are known to slowly release nutrients but over a long term. Buxton and Wenwie (1999) point out that the management of nutrient solution is of great importance when growing plant hydroponically. The number of days to maturity in lettuce is significantly affected by the volume of aggregates inside the styropor cup. Lettuce grown in 9 oz cup was harvested one day earlier compared to those grown in 6 oz cup. This may be because bigger aggregate volume can store more water and nutrients for faster plant growth and development.

Days to flowering and first harvest of sweet pepper

The number of days from transplanting to flowering and first harvest in sweet pepper was significantly affected by the nutrient source. Sweet pepper grown in CHS flowered and was harvested earlier compared to those under the other treatment. This result may again be attributed to the effects of the balanced and optimum amount of nutrients to the plant that caused earlier flowering and harvesting. According to van Winden (1998), precise nutrients added to the plant are a major advantage for the growth and development of the plant. Marschner, (1995) added that uniform absorption of nutrients makes plant grow faster. Volume of aggregates also significantly affected the number of days from transplanting to flowering and the number of days from transplanting to first harvest of sweet pepper. Plants in bigger cup volume had earlier flowering and harvesting of fruits. Again, the results showed that those roots developed and grew faster and absorbed more nutrients due to larger space provided by 9 oz aggregate volume in the styropor cup.

Plant height of lettuce and sweet pepper

Generally, plant height of lettuce and sweet pepper had an increasing trend. At this early stage, 1st-3rd week from transplanting, lettuce grown in CHS were significantly taller compared to other treatment until maturity. Similarly, there was significant effect of the nutrient source on the plant height at all stages in sweet pepper except at 2nd week from transplanting. Sweet pepper grown in CHS was significantly taller. Peet, (2002), reported that sweet pepper is considered heavy feeder because of its rapid growth and long productive life. When its nutrient requirement is not satisfied, deficiencies and disorders would tend to manifest in their growth. Plant height of lettuce was significantly affected by aggregate volume from 2nd to 3rd week from transplanting. At the early stage plant height of lettuce was not affected yet by volume of aggregates. Sweet pepper, on the other hand, grown in 9 oz aggregate volume from 1st to 9th week from transplanting were significantly taller except at the 2nd week compared to those grown in 6 oz volume of styropor cup. Result showed that growth of lettuce and sweet pepper was favored significantly by bigger volume of aggregate. This presumably because bigger volume of aggregate can hold more nutrients solution for absorption by the plants. In addition, the volume of aggregates may be critical since the aggregates are aerated unlike the nutrient solution itself where dissolved oxygen is limiting because there is no forced aeration provided. Oxygen is important for root respiration and one of the critical factors for plant growth and development.

Number of leaves of lettuce and sweet pepper

In general, there is increasing number of leaves with time in lettuce and sweet pepper. Number of leaves of lettuce at 1st to 3rd week after transplanting was significantly affected the number of leaves produced by sweet pepper in all stages of its growth. Lettuce and sweet pepper grown in CHS produced more leaves compared to those grown in HFM in all stages for their growth. The number of leaves is one important varietal characteristic because this is directly related to the rate of photosynthesis which is mainly responsible for growth of sinks. It was noted that plants grown in HFM experienced yellowing of leaves especially the older ones. Moreover, the plants had less branching and tended to senesce earlier. Alejar and See (1999) stated that stunted growth and chlorosis are symptoms of nitrogen deficiency while inhibition of bud development and die back of the root tips are symptoms of calcium deficiency (www_quickgrow.com/gardening_article/.nutrients. html). It is then probable that the available nutrients in HFM were below optimum for the crop. Volume of aggregates showed significant effect on the number of leaves on the third week but not on the 1st and 2nd week. Sweet pepper, on the other hand, was significantly affected by the volume of aggregated at all stages of its growth. Lettuce and sweet pepper grown in 9-oz cup produced more leaves compared to those grown in 6 oz cup. Again results showed that bigger aggregate volume holds more nutrients needed by the plants thus, enabling it to produce more roots which can take up more nutrients to be transported to the different parts of the plant.

Leaf Nutrient Content and Nutrient Uptake by the Plant

Leaf nutrient content and uptake vary considerably among plants parts and they also change during the growth cycle (Howeler, 1978). N, P, and K contents vary with time in roots, stems and leaves. For diagnostic purposes, however, he suggested that at three months after planting, the leaf blade of the uppermost fully expanded leaves (4th or 5th leaf from the top). However, in this study, the plant leaves were used due to the low foliar dry matter production of the hydroponically grown plants. Less sample material for analysis would be available if the above recommendation were followed. The effects of nutrient source and volume of aggregates on the uptake of nitrogen, phosphorous and potassium by lettuce and sweet pepper.

Results show that lettuce and sweet pepper supplied with CHS had higher leaf N, P and K content than those in FHM. This could be attributed to improved plant growth of the said treatments due to increased available N, P and K supplied by CHS. With such improved growth of lettuce and sweet pepper larger amount of N, P and K can be extracted from the solution and can be translocated to the shoots leading to greater accumulation of nutrients in the leaves. It is also appeared that nutrient concentration in the leaf was slightly greater in plants grown in 9-oz aggregate. This was presumably bigger aggregate volume had more room for root growth, as previously discussed, allowing for greater nutrient uptake. Total nutrient uptake was greater in plants supplied with CHS. Also, those grown in 9-oz aggregate had greater total nutrient uptake. The greater nutrient uptake is related to greater nutrient concentration in the leaf as well as to greater biomass accumulation.

Yield and Yield Components of Lettuce

CHS resulted to the production of bigger and greater number of marketable heads while HFM resulted to the production of more non-marketable heads. This was probably due to the higher nutrient uptake of the plants in the former that the latter.

The volume of aggregate did not significantly affect the polar head diameter of lettuce. However, those grown in 9-oz cup had wider head equatorial diameter, more marketable heads and fewer non-marketable heads. The weight of marketable head and herbage yield were significantly affected by nutrient source. Lettuce grown in CHS had heavier weight of marketable heads and herbage yield compared to those grown in HFM.

Volume of aggregated did not significantly affect the weight of marketable and non-marketable heads but affected on the average yield per plant. Lettuce grown in 9-oz volume of styropor cup had more yields per plant and herbage yield per treatment compared to those grown in 6 oz volume of styropor. This reinforces the contention that bigger volume could produce more roots inside the container and thus takes up more nutrients.

The interaction effects between nutrient source and volume of aggregated of lettuce on the length and weight of roots outside the cup were significant. In lettuce plants supplied with CHS, root outside the 9 OZ were shorter compared to those grown in 6 oz cup. However, in those supplied with HFM, root length did not vary with the volume of aggregate. Under CHS, root weight and average yield per plant of lettuce were greater in the 9-oz aggregate volume to 6 oz volume. The parameters, however, were comparable in the two aggregate volumes under HFM. Results suggest that the yield supplied with HCS can be further increased if aggregate volume is increased from 6-oz to 9-oz, but not HFM is used as a nutrient source.

Yield and yield Components of Sweet pepper

Nutrient sources had significant effect on the fruit size and marketable fruits of sweet pepper. Those grown in CHS produced fruits with significantly wider diameter compared to those in HFM. The availability of nutrients in optimum amounts released by the commercial hydroponics solution may have enhanced production of bigger fruits. Volume of aggregate also significantly affected the diameter, number of marketable and total number of fruits of sweet pepper. Those grown in 9 oz styropor cup had wider fruit and more marketable and total fruits produced. The weight of marketable fruits, total yield and herbage yield were significantly affected by nutrient source. It was found that plants in commercial hydroponics solution had higher marketable and total fruit yield, compared with the plants grown in HFM. This may have been because the nutrient present in HFM were not really available and thus limiting the uptake of nutrients by the plants.

The weight of fruits, were not significantly affected by the volume of aggregated. This is despite the significantly higher herbage yield of sweet pepper grown in 9-oz volume styropor cup. Thee ample and readily amount of nutrients stored in bigger container may have enhanced growth and development of the vegetative parts of the plants but did not ensure yield advantage over that given in smaller cups. The bigger aggregate volume may have allowed for more root growth and enhance the capability of the plant to take up more nutrients, however, this did not result to any other yield advantage. The interaction effect of nutrient sources and volume of aggregates in sweet pepper on the growth and yield parameters were both not significant.

Cost and Return Analysis

The protective structure used in this study could accommodate 480 styropor boxes so cost and return analysis was based on this number of boxes. The expenses in sweet pepper and lettuce production per 480 boxes under different nutrient sources and volume of aggregates and the cost and return analysis. Despite the higher yield of lettuce and sweet pepper fed with CHS net returns was lower compared to those fed with HFM because of lower cost of the latter nutrient source. The 9 oz volume of styropor cup which produced slightly higher marketable yield had higher net income compared to those grown in 6-oz styropor cup for both lettuce and sweet pepper.

Conclusion

The CHS enhanced the growth and yield characteristics of lettuce and sweet pepper that resulted to increased total fruit yield relative to HFM. The use of 9 oz styropor cup proved better compared to 6-oz styropor cup as this volume of aggregates enhanced growth and development of both lettuce and sweet pepper and resulted to slightly greater yield and consequently higher net returns. The bigger aggregate volume allowed more room for root growth. Because of high cost of CHS, net returns of the plant fed with these nutrient sources were lower compared to those fed with HFM.

Recommendation

Larger volume of aggregate should also be used especially for crops which inherently accumulate greater biomass and which have longer maturity. The nutrient concentration of different nutrient sources including the commercial hydroponics solution should be optimized for different crops.

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