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Nutrient Dynamics Evaluation in Utilization of Household Greenhouse Module for Hydroponic Production of Mint (*Mentha Arvensis* L.)

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Hydroponic nutrients are the basis behind the success of any indoor garden. By focusing on the two most important solution factors - nutrient balance and nutrient concentration, the hydroponic solution will give maximum growth and yields. Hence, this study looked at the dynamics of nutrient solutions for mint production, in terms of location and time, in a household hydroponics system module. The systems' environment parameters such as pH, temperature, electrical conductivity and total dissolved oxygen were also monitored and their effects to nutrient dynamics had been examined. Based on the data gathered, nutrients in a household set up hydroponics varied as they traveled from the tank, growing tubes, raft cultures until they reached the collection point. Likewise, changes in nutrients solutions happened in time. Moreover, with regard to results in nutrient dynamics in different collection points, it was found out that it was only during the first and third weeks when the highest nutrient concentrations were observed in control point. In week 2 and week 4, highest concentration values were seen in collection points 2 and 1, respectively. In terms of nutrient dynamics at different times there were no significant difference on the following nutrient concentrations: copper (Cu), iron (Fe) and manganese (Mn) while significant difference from Weeks 1 to 4 was observed in calcium (Ca), magnesium (Mg) and nitrate nitrogen (NO_3-N). The presence of 11 common nutrient deficiencies observed in the hydroponics production of mint could be attributed to deficiencies in total nitrogen, potassium, phosphorous and iron.

Keywords: hydroponics, *Mentha arvensis* L., mint, nutrient dynamics

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Introduction

Today, the world is beset with the challenges of producing sustainable food for human consumption. With the fast-paced growing population, water consistently gets scarcer and the biological effect of transportation makes the hydroponics as the best decision for business and for home crop production. The human population is expanding, and is anticipated to increase from 6.9 billion to 9.3 billion people within the next 35 years (United Nations, 2011). A parallel augmentation in the interest for sustenance is inferred, and appraisals guarantee that nourishment creation will be multiplied to remunerate the needs of individuals (Bellona Foundation, 2009).

Hydroponics is the cultivation of plants without utilizing soil, with the sources of nutrients solution or nutrient-enriched water, and that an inert mechanical root support such as sand or gravel may or may not be used (Jones, 2005). Since it does not require natural precipitation or fertile land in order to be effective, it presents people who are living in arid regions with a means to grow food for themselves and for profit.

Mint can be easily cultivated. This aromatic herb plant has a multitude culinary uses and has been proclaimed as one of the top 10 herbs authorized by the Department of Health (DOH) for its antiseptic, anti-cancer, diuretic, anti-spasm and anti-emetic activities (Abe and Ohtani, 2012).

The essential problem with hydroponics farming arises through its use of a mineral based solution to grow and nourish the plants instead of soil. Depending on the stage of plant development, some elements in the nutrient solution will be depleted more quickly than others. Probably no aspect of hydroponics growing is as misunderstood as the constitution and use of nutrient solutions. The complex interrelationships between composition and use are not understood by many growers, and it is this aspect of nutrient solution management for which much of the literature unfortunately provides little or no help.

As this study explored on the nutrient dynamics in mint production using household hydroponics system, it will provide not only the neophyte growers but also the pro growers the ticket to successful hydroponic gardening including a quality and balanced nutrient solution essential to getting the most from their high-tech garden.

Materials and methods

Nutrient Application

A maximum height of solution in the tanks was maintained daily to its maximum at 35 cm corresponding to 5.37 liters of solutions. A strict monitoring of pH and TDS was checked twice daily at 7:00 am and 5:00 pm using a hand-held digital meter. The nutrient solutions were replenished as needed.

Appropriate levels of pH and TDS were maintained for every growth stages of the plant. An equal amount of solution A and solution B was required to maintain the pH and TDS.

Monitoring Environmental Factors and Water Quality

Environmental factors and water quality parameters were designed to meet the requirements of a compromised ecosystem conducive to all species. These parameters were compared to the actual conditions. Environmental factors were obtained from the air thermometer and hygrometer for the relative humidity. Hand-held water quality monitors were used to measure pH, electrical conductivity, total dissolved solids and water temperature at the greenhouse. Water quality data were collected once in the early morning (AM) and once in the late afternoon (PM). The data were collected just before sunrise and just before sunset when the daily minimum and maximum dissolved-oxygen concentrations would be expected, respectively as suggested by Krstolic and Hayes (2014).

Determination of Growth, Yield and Nutrient Deficiency

There were five plants randomly taken from each growing tube and raft culture as representative samples. The yield of mint production was evaluated by weighing fresh leaves harvested after four weeks.

Meanwhile, the symptoms of deficiencies in macronutrients and micronutrients with the evolution of symptoms and descriptions were based on the first signs of discoloration until symptoms became well established, when plant samples were harvested.

Plant height were defined as the distance between the stem, at the substrate level to the apex. The measurement of the height of the plant from substrate was made with a measuring tape. Leaf area index was measured every week using vernier caliper. Three leaves were collected at random from two plant strata (old leaves and young leaves), and total six samples per plant. In each leaf, length and the greatest width of the blade were measured (Silva *et al*., 2014).

Results

Nutrient Dynamics at Different Collection Points

The succeeding figures illustrate the nutrient dynamics in different collection points. For week 1, bicarbonate (298 mg/L) had the highest concentration obtained in the control point. This was followed by calcium (55.7 mg/L) in collection point 1, nitrate nitrogen (55.5 mg/L), sodium (46.8mg/L) in control point and chloride (28.96 mg/L) in collection point 1 (Figure5).

Moreover, calcium, magnesium, sodium, chloride and iron show increased concentration from control point to collection point 1 and decreased in collection point 2. However, EC, sulfate, total nitrogen, phosphorus, potassium, nitrate nitrogen, ammoniacal nitrogen, boron, copper and manganese shows decreased concentration in collection point 1 to collection point 2.

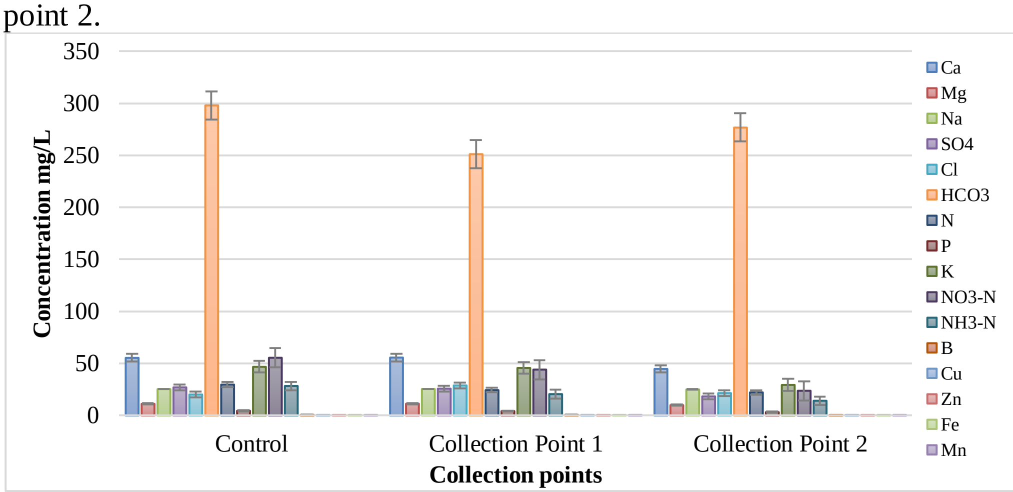

Figure 1. Nutrient dynamics at different collection point after 1 week

During the second week the highest nutrient registered was seen in collection point 2. As shown in Figure 2, the top five nutrients with the highest concentration are as follows: bicarbonate (479.5 mg/L), sulfate (163.565 mg/L), potassium (140.65 mg/L) nitrate nitrogen (108.5 mg/L) and calcium (88.32 mg/L). The high concentration values in the previous three nutrients were obtained in control point 1.

Moreover, EC, calcium, magnesium, chloride, total nitrogen, nitrate nitrogen, boron, copper and iron shows increased concentration from control to collection point 1 and decreased when it flows down to collection point 2. Sulfate, bicarbonate, phosphorus and zinc shows increased concentration while pH, sodium, potassium shows decreased concentration in collection point 1 and collection point 2.

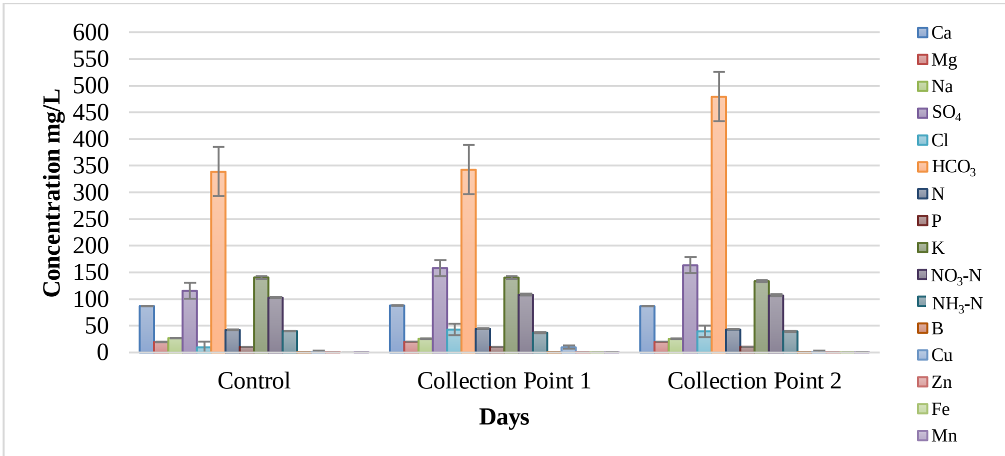

Figure 2. Nutrient dynamics at different collection point after 2 weeks

Figure 3 shows, during the third week, the highest nutrient concentration bicarbonate (502.2 mg/L) was obtained in control point. Next to bicarbonate is potassium (292.7 mg/L), sulfate (246.7 mg/L), calcium (218 mg/L) and nitrate nitrogen (167 mg/L). The high concentration values for potassium and sulfate were obtained in collection point 2, while for calcium and nitrate nitrogen the values were gathered from collection point 1.

Increased concentration from the collection points were observed in magnesium, total nitrogen and phosphorus while decreased concentration in bicarbonate, ammoniacal nitrogen and manganese. Moreover, EC, sodium, sulfate, chloride, potassium, boron, copper and zinc obtained decreased concentration in collection point 1 but increased in collection point 2. However, calcium and nitrate nitrogen obtained increased concentration in collection point 1 but decreased in collection point 2. There are no changes in concentration in iron.

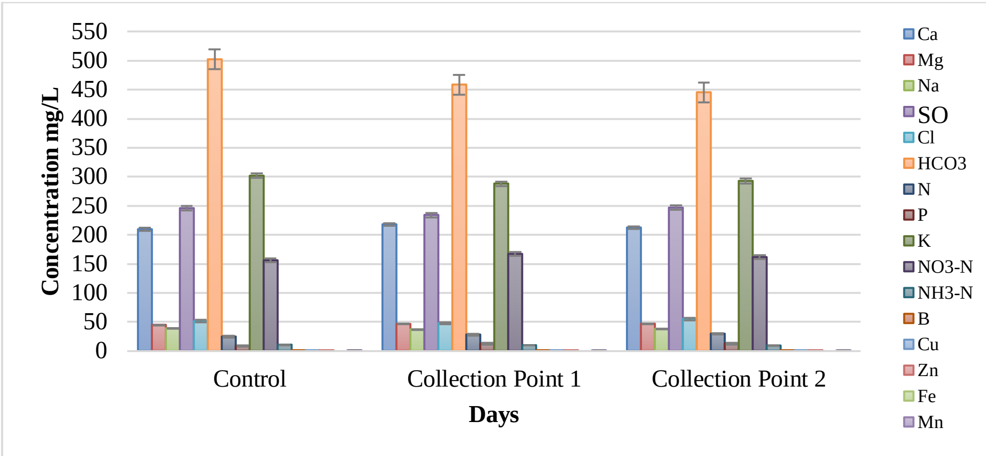

Figure 3. Nutrient dynamics at different collection point after 3 weeks

In the last week, an increase in nitrate nitrogen's concentration (219.5 mg/L) followed by sulfate (180 mg/L) was obtained from collection point 1. However, bicarbonate (133.550 mg/L), and calcium (173.75 mg/L) highest values were obtained from collection point 2 while chloride (133.4 mg/L) was obtained in control point (Figure 4).

An increase in concentration was found in calcium, magnesium, sodium, bicarbonate, boron, zinc and manganese from collection point 1 and collection point 2. pH, chloride, total nitrogen, ammoniacal nitrogen and iron obtained decreasing concentration as it flows down in collection point 2. Moreover, a change in concentration was observed in EC, sulfate, phosphorus, potassium, nitrate nitrogen and copper shows increased concentration in collection point 1 and decreased in collection point 2.

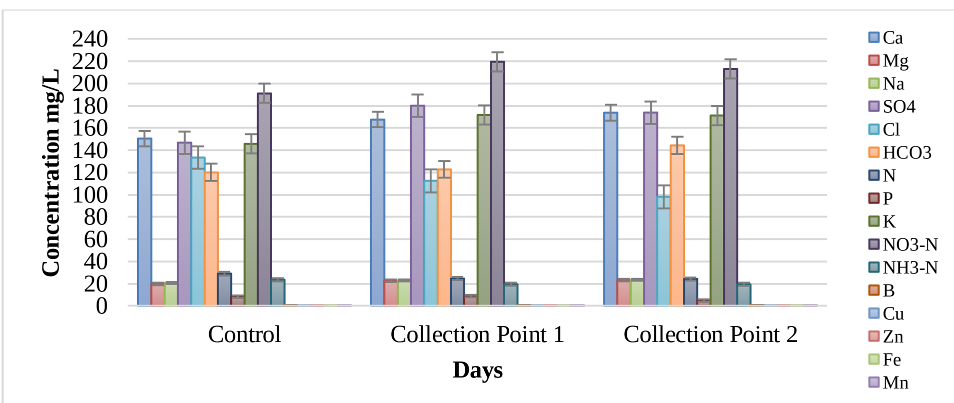

Figure 4. Nutrient dynamics at different collection point after 4 weeks

Findings obtained from Figures 1 to 4 can be attributed to the interaction between and among plant nutrients. Some elements work in synergy – they stimulate the uptake of others and increase their availability while some elements are antagonistic – they interfere with the uptake or availability of others. High levels of a particular nutrient can interfere with the availability and uptake of other nutrients. The nutrients which interfere with one another are referred to as antagonistic. For instance, high nitrogen levels can reduce the availability of boron, potash and copper; high phosphorous levels can influence the uptake of iron, calcium potash, copper and zinc; high potash levels can reduce the availability of magnesium (Jones, 2005).

Nutrient Dynamics in Different Times

Table 1 summarizes the nutrient dynamics from week 1 to week 4. As presented, there was no significant difference on the following nutrient concentrations: copper (Cu), iron (Fe) and manganese (Mn); while significant difference from Weeks 1 to 4 was observed in calcium (Ca), magnesium (Mg) and nitrate nitrogen ($N0_3$-N).

For the nutrients that obtained significantly different values, it shows that calcium, magnesium and nitrate nitrogen obtained their lowest concentration in week 1 with 50.25mg/L, 10.65mg/L and 33.98mg/L, respectively. Moreover, highest concentration was obtained in week 3 for calcium and magnesium with 215.25 mg/L and 46.65 mg/L while in nitrate nitrogen is in week 4 with 216.25mg/L.

Of all the nutrients, only zinc (Zn) had concentrations that fell within the range for four weeks while calcium (Ca), magnesium (Mg) and copper (Cu) have ppm concentrations that fell within the range for three weeks. Only week 2 and week 3 concentrations for manganese (Mn) fell within the range. On the other hand, iron (Fe), total nitrogen (N) and phosphorus (K) concentrations for four weeks fell below the range.

Table 1. Changes in nutrient concentration after week 1, week 2, week 3 and week 4 of mint production

CONCENTRATIONS	TIME			
	Week 1	Week 2	Week 3	Week 4
Calcium (Ca), mg/L	50.25^{a}	87.59^{b}	215.25^{d}	170.63^{c}
Magnesium (Mg), mg/L	10.65^{a}	20.14^{b}	46.65^{d}	23.15^{c}
Sodium (Na), mg/L	25.28^{a}	25.94^{a}	37.57^{b}	23.22^{a}
Sulfate (SO4), mg/L	22.12^{a}	160.93^{b}	240.43^{c}	176.93^{bc}
Chloride (Cl), mg/L	25.26^{a}	41.43^{a}	51.51^{a}	105.32^{b}
Bicarbonate (HCO3), mg/L	263.93^{ab}	411.25^{b}	452.03^{b}	133.55^{a}
Total Nitrogen (N), mg/L	23.34^{a}	43.93^{c}	28.87^{b}	24.38^{a}
Phosphorus (P), mg/L	3.74^{a}	10.90^{bc}	12.44^{c}	6.92^{ab}
Nitrate Nitrogen (NO3-N), mg/L	33.98^{a}	107.75^{b}	164.25^{c}	216.25^{d}
Ammoniacal Nitrogen (NH3-N), mg/L	17.40^{b}	38.54^{c}	9.52^{a}	19.38^{b}
Copper (Cu), mg/L	0.06^{a}	4.93^{a}	0.16^{a}	0.21^{a}
Zinc (Zn), mg/L	0.15^{a}	0.29^{b}	0.35^{b}	0.30^{b}
Iron (Fe), mg/L	0.05^{a}	0.09^{a}	0.00^{a}	0.20^{a}
Manganese (Mn),mg/L	0.08^{a}	0.52^{a}	0.71^{a}	0.23^{a}

*Means with the same letter superscript in the same rows are not significantly different from each other at 5% level of significance using Tukey's HSD.

Nutrient Deficiency Symptoms

Based on the results, findings with regard the most common and least common deficiency, weeks when the most number of nutrient deficiency symptoms were noted and the positions where the most number of deficiencies occurred can be inferred.

The highest percentage of symptoms was seen in week 4, position 7 (23.81%). This was followed by week 2, position 7 (19.84%); Week 3, position 1 (11.67%) and Week 1, position 7 (10.32%).

In terms of the percentage of symptoms observed in four weeks, the top three symptoms were chlorosis (13.45%), drying of leaves (7.35%) and yellowing of leaf margin (4.93%).Brown necrotic patch was the most common deficiency that was observed in Week 2 in four positions (1, 3, 4 and 7) while the least symptoms observed deficiency were necrotic leaf margin and stunted growth in Weeks 2 and 4, and purple veins in week 2.

With regard to positions, the most number of symptoms were seen in position 7 (chlorosis, brown necrotic pattern, leaf curling, wilting, stunted growth and dying of leaves), followed by position 4 (burnt leaf tip, chlorosis, brown necrotic patch, yellowing of leaf margin and dying of leaves). Position 3 (bronze color leaf, brown necrotic patch, yellowing of leaf margin and leaf curling) ranked third, while position 1 (bronze color leaf, burnt leaf tip and dying of leaves) and position 2 (yellowing of leaf margin, leaf curling and wilting) ranked fourth. Two symptoms, bronze color leaf and necrotic leaf margin, were seen in position 5. The least number of symptom was spotted in position 6 (bronze leaf tip).

Relationship of Deficiency Symptoms to Nutrient Dynamics

The manifestation of marginal chlorosis (week 1, week 2 and week 4), necrotic leaf margin (week 4), burnt leaf tip (weeks 1, 3 and 4), leaf curling (weeks 2 and 4) and stunted growth (week 4) could be attributed to potassium deficiency.

Iron deficiency was manifested in the alterations of young leaf (week 1 to week 2), purple veins (week 2), chlorosis (weeks 1, 2 and 4) yellowing of leaf margin (week 2), stunted growth (week 4) and wilting (weeks 2 and 4). Iron deficiency, once developed in the plant, is very difficult to correct.

Further symptoms of phosphorous deficiency include necrotic leaf margin, burn leaf tip, stunted growth and purple coloration of foliage which were also seen in the mint produced hydroponically. The nutrient deficiency also included manifestation of rough and coarse stem leading to overturning. The leaves showed necrosis, progressing to the fall and reduced growth in height (67.30 cm^2) and small leaf area (116.43cm^2).

Discussions

Results revealed that temperature was within the range, while average relative humidity, water temperature and pH value in the hydroponics system were above the normal range.

Nutrient dynamics in different collection points, were found only during the first and third weeks when the highest nutrient concentrations were observed in the control point. Nutrient dynamics at different times were not significantly different on the following nutrient concentrations: copper (Cu), iron (Fe) and manganese (Mn) while significant difference from weeks 1 to 4 was observed in calcium (Ca), magnesium (Mg) and nitrate nitrogen (NO3-N).

The fundamental component in hydroponic system is represented by the nutrient solution. The control of nutrient solution concentration, referred as electrical conductivity or osmotic pressure, allows the culture of a great diversity of species. Moreover, the accurate control of nutrient supply to the plant represents the main advantage of soilless culture. Additionally, the regulation of pH, root temperature among others factors, leads to increased yield and quality.

Based on Magundhan's (2011) range of nutrient concentration of common element in growing herb, concentrations that fell below the range for four consecutive weeks include: magnesium (Mg), total nitrogen (N), phosphorus (P), zinc (Zn), iron (Fe) and manganese (Mn). Meanwhile, calcium (Ca), nitrate nitrogen (NO_3-N) and copper (Cu) concentrations fell below the range in three weeks except for week 3 for calcium, week 4 for nitrate nitrogen and week 4 for copper in which the ppm obtained are higher than the range.

It can be inferred that three nutrient concentrations (iron, total nitrogen, and phosphorus) consistently fell below the range of nutrient concentration based on Barley (1996) and Magundhan's (2011) ranges.

Mints growth parameters and yield were determined through its height, node, root and weight. The highest mean average for its height and number of nodes were obtained in Week 4. In terms of root length, the highest mean was observed in position 3. Moreover, position 1 obtained the highest mean weight.

The presence of 11 common nutrient deficiencies observed in the hydroponics production of mint could be attributed to the deficiencies in total nitrogen, potassium, phosphorous and iron.

Findings on the relationship of nutrient dynamics to deficiency symptoms conformed to that of Silva *et. al.* (2014) when they studied the growth and visual symptoms of nutrient deficiencies in young Mentha piperita plants where they concluded that nitrogen and calcium are the first to express nutrient deficiency symptoms followed by phosphorus, potassium, magnesium, sulfur, boron, copper, iron and manganese. According to them, the most limiting nutrient for the growth of M. piperita based on total dry matter and leaf area is nitrogen. In relation to stem, aerial part and total dry matter the omissions of nitrogen, calcium, boron and copper were most limiting and in the root the omission of phosphorus and born was the most outstanding.

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