Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
www.phytojournal.com
JPP 2020; 9(5): 2095-2099
Received: 30-06-2020
Accepted: 28-08-2020

ST Patil
Ph.D. Scholar, Dr. B.S. Konkan Agricultural University, Dapoli, Maharashtra, India

Kadam US
Professor and Head, Department of Irrigation and Drainage Engineering, DBSKKV, Dapoli, Maharashtra, India

Mane MS
Professor and Head, Department of Irrigation Irrigation Water Management, MPKV, Rahuri, Maharashtra, India

Mahale DM
Ex- Professor and Head, Department of Soil and Water Conservation Engineering, DBSKKV, Dapoli, Maharashtra, India

Dekale JS
Professor (CAS), Department of Agril. Economics, DBSKKV, Dapoli, Maharashtra, India

Corresponding Author:
ST Patil
Ph.D. Scholar, Dr. B.S. Konkan Agricultural University, Dapoli, Maharashtra, India

Hydroponic nutrient solution: A review

ST Patil, Kadam US, Mane MS, Mahale DM and Dekale JS

Abstract
Nutrient solution plays an important and essential source of nutrient for hydroponic crops. The formulation of the nutrient solution, EC and pH, concentration, solution temperature are the major factors influencing the quality of nutrient solution. Normally seventeen elements are considered essential for most plants, those are carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, iron, copper, zinc, manganese, molybdenum, boron, chlorine and nickel. The carbon, hydrogen, oxygen are received directly from atmosphere and other are to be supplied from the nutrient solution.

Keywords: Hydroponic nutrient, potassium, calcium

Introduction
Steiner, (1961) [32] stated that nutrient solution for hydroponic systems is an aqueous solution containing mainly inorganics ions from soluble salts of essential elements for plants. Eventually, some organic compounds such as iron chelates may be present. In 1938, Dennis R. Hogland and Daniel I. Arnon at university of California developed water culture methods for growing plants without soil, Pandey *et al*., 2009 [23]. He shown that an essential element has a clear physiological role and its absence prevents the complete plant life cycle. Salisbury Ross (1994) reported that elements essential for most plants are carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, iron, copper, zinc, manganese, molybdenum, boron, chlorine and nickel. With the exception of carbon (C) and oxygen (O), which are supplied from the atmosphere, the essential elements are obtained from the growth medium. Trejo-Téllez *et al*. (2007) observed that elements such as sodium, silicon, vanadium, selenium, cobalt, aluminum and iodine, are considered beneficial because some of them can stimulate the growth. They can compensate the toxic effects of other elements, or may replace essential nutrients in a less specific role. The most basic nutrient solutions considers in its composition only nitrogen, phosphorus, potassium, calcium, magnesium and sulphur and they are supplemented with micronutrients. McEvoy (2000) showed for non organic hydroponic production the bulk of the plant nutrients are supplied in available forms and it is the management of the fertilizers**.**

Electrical Conductivity & pH of the nutrient solution
The electrical conductivity and pH has paramount importance in formulation of the hydroponic solution. Alberto *et al.* (2003) [2] showed that the electrical conductivity and pH of nutrient solution should be maintained between 2.6-3.4 mS cm^{-1} and 5.6-6.0 respectively. Ahn and Ikada (2004) [1] found that optimal pH of 5 to 7 and optimal concentration of nutrient solution is ¼ to 1 unit of standard solution was found most suitable for hydroponic cultivation of Chinese Chive. Urrestarazu (2004) [36] observed the changes in the pH of a nutrient solution depending on the difference in the magnitude of nutrient uptake by plants, in terms of the balance of anions over cations. Samarakoon *et al*. (2006) [29] found that higher EC hinders nutrient uptake by increasing osmotic pressure, whereas lower EC may severely affect plant health and yield. Sonneveld & Voogt (2009) [31] reported that the nutrient composition determines electrical conductivity and osmotic potential of the solution. The ideal EC is specific for each crop and dependent on environmental conditions, however, the EC values for hydroponic systems range from 1.5 to 2.5 ds m-1. Libia *et al.* (2012) [12, 34] revealed that the control of nutrient solution concentration, referred as electrical conductivity or osmotic pressure, allows the culture of a great diversity of species. The accurate control of nutrient supply to the plant represents the main advantage of soilless culture. The regulation of pH, root temperature among other factors, leads to increased yield and quality. Anonymous (2015) [3] observed that most of the principles applied to soil fertilizers also apply to hydroponic fertilizer or nutrient solutions. The recommended pH for hydroponic agriculture is in between 5.5 to 6.5.

This is because the overall availability of nutrients is optimized at slightly acidic pH. The EC (electrical conductivity) is also a limiting factor in plant production. Each crop has a threshold at which water salinity will start negatively affecting the produce. The optimal EC levels range from 1.5 to 4 ds m^{-1} according to crop and its sensitivity to different salinity levels, managing and maintaining pH and EC is a key component of successful hydroponic farming. Maneejantra *et al.* (2016) [18] worked on an Enshi formula solution which was having EC 2.2-2.4 dS m^{-1}. They noted increasing trend of root fresh and dry weight was similar to those of shoots due to nutrient solution, environmental condition and hydroponic system. Jovicich and Cantliffe (2000) [10] shown there was a positive linear relationship (r = 0.82) between the percentage of plants with epidermis wounds and the EC. Kong and Iersel (2009) [12] found that plants fertilized with constant fertilizer concentration having EC of 0.52 and 1.24 ds $m^{-1}$was estimated to be optimal for Begonia and Petunia respectively. When leachate was maintained at a constant EC 1.0 and 1.7 dS m^{-1} were estimated to be optimal for Begonia and Petunia respectively. Libia *et al.* (2012) [13, 34] showed that changes in the pH of a nutrient solution depend upon the difference in the magnitude of nutrient uptake by plants in terms of anions over cations. The incorporation of ammonium as N source in the nutrient solution regulates the pH. Ammonium depresses the pH of nutrient solution even in the presence of nitrate. The pH regulation is closely related to the concentration of HCO_3^- and CO_3^{2-} when an acid is applied. Electrical conductivity is also modified by plants as they absorb nutrients and water from the nutrient solution. The temperature of the nutrient solution has a direct relation to the amount of oxygen consumed by plants. There is inverse relation of temperature with oxygen dissolved in solution. The solubility of fertilizers as well as root uptake also gets affected by temperature of nutrient solution. It was also found that the level of oxygen in nutrient solution decreases below 3-4 mg. L^{-1} which will inhibit root growth and changes to a brown colour which is first symptom of oxygen lack. Oxyfertigation is also used for nutrient solution. They concluded that substrate under long cultivation period causes increase of organic matter content and microorganism activity which could lead to an increase of the competition for oxygen in the root environment. Anonymous (2015) [3] recommended the pH for hydroponic agriculture is in between 5.5 to 6.5. This is because the overall availability of nutrients is optimized at slightly acidic pH. The optimal EC levels range from 1.5 to 4 ds m^{-1} according to crop and its sensitivity to different salinity levels. Soares *et al.* (2015) [30] found in their experiment that the mean values of absolute growth rate of shoot growth rate (AGR-SFM) and relative growth rate (RGR-SFM) are function of the electrical conductivities of water. The study concluded that increase in the salinity caused linear reduction on the water consumption.

Osmotic potential and Drainage of nutrient solution

Trang *et al.* (2010) [35] concluded that growth of the two brassica varieties was best at drained root conditions, while *L. sativa* and *I. aquatica* grew best with half-flooded and flooded roots respectively. Lopez-Pozos *et al.* (2011) [14] found that inadequate oxygenation of the nutrient solution (NS) in recirculating hydroponic systems leads to root hypoxia in several plants as a result of low oxygen solubility. Hypoxia affects crop nutrient and water absorption and results in reduced crop yield. More rapid changes in NS were associated with a higher quantity of dissolved oxygen. Park and Kurata (2019) used half strength Yamazaki nutrient solution with micro and macro bubble treatment and results revealed that pH, EC and ORP in the nutrient solution did not differ much with generation of micro and macro bubbles. From this study they also observed that significant increase in growth was in the micro bubble condition where samples showed 2.1 times greater fresh leaf weight and 1.7 times greater dry leaf weight than the macro bubble sample. Leaf number, leaf length and leaf width of lettuce grown in the macro bubble condition were also significantly higher. This may be due to larger specific surface area of micro bubbles. Negative electron charges on micro bubble surface may help roots absorb nutrient salts because micro bubbles can attract positively charged ions. Mairton *et al.* (2016) [17] evaluated the hydroponic system under different intervals of nutrient solution. The water consumption increased along freshwater crop cycle while for brackish water consumption decreased up to 33.10%. This is due to osmotic potential. Rafaela *et al.* (2017) [26] revealed that the production during the lettuce cultivation cycle reduced considerably with the increase in electrical conductivity and ultimately osmotic pressure. The exposure stress to saline condition interferes in fundamental plant functions such as photosynthesis and protein synthesis. The saline stress inhibits the plant growth by osmotic effect restricting the availability of water besides nutritional disorders. The hydroponic production of lettuce was satisfactory in NFT system for electrical conductivity of nutritive solution up to 3.5 ds m^{-1}.

Concentration of nutrient solution

Vernieri *et al.* (2006) [37] used 0.3v mL L^{-1} bio-stimulant (Actiwave) with NS10% shown that yield was higher in treatments with Actiwave of lower concentration. Kong and Iersel[1] (2004) [11] reported that shoot, total dry weight and leaf area increased greatly with increasing nutrient solution concentration from 0.125 to 1.0x while leaf photosynthesis, transpiration and stomatal conductance decreased with increasing nutrient solution concentration. They revealed that 1.0 to 2.0x concentration of Hoagland solution results in maximum growth. The plant produces leaf area more efficiently at high fertilizer concentration. Burnett *et al.* (2008) [5] revealed that the plants fertilized with either highest (80 mg. L^{-1}) or lowest (0 mg. L^{-1}) concentrations had significantly shorter stems and smaller shoot dry weights and leaf areas than plants fertilized with 20 to 60 mg. L^{-1} P. Fan flower fertilized with 0, 60 and 80 mg. L^{-1} had fewer flowering branches and flowers compared with plants fertilized with 20 to 40 mg. L^{-1} P. Nada *et al.* (2010) [20] suggested that the critical concentration of Boron in nutrient solution is 4 ppm for long term hydroponic cultivation of tomatoes. Renata *et al.* (2012) [27] found the plants fed with the medium and highest doses of nitrogen had significantly higher weight of fresh and air dry herb. Bever (2013) [4] observed that photosynthetic rate, evapotranspiration, intercellular CO_2 concentration and chlorophyll content of Beta Vulgaris were generally higher in treatment with nitrogen which was readily available to plants. Mabako *et al.* (2017) reported that plants fertigated at 25 nutrient solution concentration had tendency towards lower marketable yield. At 75 percent of the nutrient solution concentration increased the total number of the fruit and yield significantly as compared to 25 percent nutrient solution concentration. Among all treatments, highest total yield, plant fresh and dry weight, highest marketable yields where no significantly different at 50, 75 and 100 percent nutrient solution concentration respectively. The highest total yield and marketable yield were obtained from plants grown at 75 and 100 percent nutrient solution concentration compared with 50 and 25 percent nutrient solution concentration.

Effect of nutrient solution on hydroponic crop production

Pardossi *et al.* (2011) [24] revealed that the closed system reduced the use of water by 21 percent and nutrients by 17-35 percent and made it possible to carry out the cultivation without any nutrient leaching. The water use, drainage and crop uptake in closed system was 6831, 0 and 6831 m^{-3} ha^{-1}. The nitrogen, phosphorous and potassium use was reduced by 35, 20 and 17 percent and saving through leaching was 100 percent under closed system over open system. Suazo-Lopez *et al.* (2014) [33] reported that it is convenient to utilize the nutrient solution at 75% in seven irrigations per day and substratum volume of 10 L for tomato production in hydroponics and greenhouse in order to obtain the highest profit (73.9%). Duyar *et al.* (2016) [7] concluded that half strength nutrient solution decreased yield. Some savings could be achieved in terms of nutrient solution consumed by the plant with the negative impact on the environment.

Ednan *et al.* (2017) [8] concluded that fertigation management through the control of the electrical conductivity of soil solution M_2 or concentration of NO^{-3} and K^+ ions M_3 promoted higher production of bell pepper in protected cultivation compared to the fertigation based on the rate of absorption of crop M_1. The fertigation can be performed using the managements control of the electrical conductivity of soil solution or concentration of NO^{-3} and K^+ ions with NK doses of 144 and 165% respectively of concentration recommended for bell pepper in hydroponic system. Luisa *et al.* (2011) [15] studied the corn salad plants grown at three root temperatures (15, 20 and 25 ^{0}C) in a floating system. Nutrient solution was renewed weekly and kept aerated while at 20^{0}C for all treatments. The results revealed that growing conditions at 20^{0}C of the nutrient solution lead to the best plant performance in terms of yield, nitrate content at leaf level, root biomass, leaf area and greenness with positive effects on post-harvest quality. At this temperature condition of the nutrient solution, it has also been observed an enhanced functionality of mechanisms involved in the acquisition of nutrients like NO^{-3}, Fe and SO_4^{2-} which are known to play important role in nitrate levels in root tissues for crop. The study concluded that level of growing medium temperature close to that of the surrounding air seems suitable. Park and Kurata (2019) observed that significant increase in growth was in the micro bubble condition where samples showed 2.1 times greater fresh leaf weight and 1.7 times greater dry leaf weight than the macro bubble sample. Leaf number, leaf length and leaf width of lettuce grown in the macro bubble condition were also significantly higher. This may be due to larger specific surface area of micro bubbles. Negative electron charges on micro bubble surface may help roots absorb nutrient salts because micro bubbles can attract positively charged ions. Ferguson *et al.* (2014) [9] revealed that continuous flow system allows refreshing of the nutrient solution at the root rapidly, allowing rapid uptake of nutrients without a large investment in root biomass. The study concluded that continuous flow systems allow lower levels of nutrients to be used with decreased costs and waste. Pardossi *et al.* (2011) [24] conducted experiment on tomato in open and closed hydroponic system. From the study they revealed that the application of closed system reduced the use of water by 21 percent and nutrients by 17-35 percent and made it possible to carry out the cultivation without any nutrient leaching, which was massive in open culture. It was also found that the commercial yield of 19.9 and 29.6 kg m^{-2} was found under open and closed system respectively. Similarly TSS was found 4.4 and 4.5 under open and closed system respectively. The water use, drainage and crop uptake in open system was 8632, 1682, 6950 while closed system shown 6831, 0 and 6831 m^{-3} ha^{-1} respectively. The nitrogen, phosphorous and potassium use was also reduced by 35, 20 and 17 percent and saving through leaching was 100 percent under closed system over open system. The crop uptake of nitrogen, phosphorous and potassium was increased by 22, 12 and 4 percent under open system respectively. Orsini *et al.* (2010) used for study La Molina nutrient solution. The results of study shown that by using floating hydroponic system of 1 m^2, yield of Lettuce (51.4 kg m^{-2} yr^{-1}), Radish (32.0 kg m^{-2} yr^{-1}), Garden beet (21.6 kg m^{-2} yr^{-1}) and Leaf beet (14.4 kg m^{-2} yr^{-1}) can be produced.

Management of nutrient solution

Wang *et al.* (2017) [38] studied the practical buffer agent capable of effectively regulating the pH level of hydroponic nutrient solution and promoting the plant growth. The study concluded that among the five treatments, the mixed acids treatments followed by HNO_3 treatment had highest plant height, fresh weight of water spinach. Rodriguez-Ortega *et al.* (2017) [28] observed the combined influence of the toxicity, osmotic effect, and nutritional imbalance seems to have been responsible for the yield loss. Chen *et al.* (2008) [6] the reservoir solution pH was adjusted by manually adding base (NaOH) or acid (H_2SO_4) solutions. The results of the designed experimental setup revealed that, during these experiments there was no overfilling of the reservoir tank, no spills from drip emitters, fewer maintains, no algae growth thus improvements solved the problems with previous system and enhanced the overall performance of the hydroponic research system. Tellez and Marino (2012) showed that in the nutrient solution parameters such as temperature, pH, electrical conductivity, oxygen content, among others can be manipulated. If these parameters are not controlled properly and in timing, advantage can be translated into disadvantages.

Conclusion

These research papers clearly states that the soilless cultivation and nutrient solution allows a more accurate control of conditions that offers possibilities for increasing production and improving quality of crops. In addition to regulation of pH and EC, concentration, root temperature, the solution quality management needs to be regulated which leads to increased yield and quality. The study reported that proper formulation and management of the nutrient solution is the key of success for hydroponic crop production.

References

1. Ahn Dang-Hyuk, Hideo Ikeda. Effects pf pH and concentration of nutrient solution on growth of hydroponically cultured Chinese Chive (*Allium tuberosum* Rattler). Hort Res. (Japan). 2004; 3(2):191-194.
2. Alberto Lizarraga, Harm Boseveld, FransHuibers, Camilo Robles. Evaluting irrigation scheduling of hydroponic tomato in Navarra, Spain. Irrigation and Drainage. 2003; 52:177-188.

3. Anonymous. Fertilizer and their use. Agricultural Extension Service. The University of Tennessee., PB-1637, 2015.
4. Bever A de, Ndakidemi PA, Laubscher CP. Effects of different combinations of Hogland's solution and Azollafiliculoids on photosynthesis and chlorophyll content in *Beta vulgaris* sub sp. Cyclafordhookgaint grown in hydroponic cultures. African Journal of Biotechnology. 2013; 12(16):2006-2012.
5. Burnett Steoananie E, Donglia Zhang, Lois B Stack, Zhongi He. Effects of phosphorous on morphology and foliar nutrient concentration of hydroponically grown scaevolaaemuta R. Hortiscience. 2008; 43(3):902-905.
6. Chen Y, Parish RL, Merhaut DJ, Bracy RP. Description of an improved hydroponic research system for screening plants for nutrient abatement in constructed wetlands. Applied engineering in agriculture, 2008, 24(5).
7. Duyar H, Kılıç CC. A research on production of baby leaf vegetables in floating system. Thehungarian academy of sciences. 2016; 29:24-27.
8. Ednan S, Nunes Junior, Jose f de, Medeires, Francisco de A de Ohiveira, Lunan A Lima *et al*. Nitrogen and Potassium fertigation in bell pepper cultivated in greenhouse using fertigation management. Revista Brasileira de Engenharia Agricola e Ambiental. 2017; 21(3):186-190.3
9. Ferguson SD, Saliga RP, Omaye ST. Investigating the effects of hydroponic media on quality of greenhouse grown leafy greens. International Journal of Agricultural Extension. 2014; 02(03):227-234.
10. Jovicich Elio, Daniel J Cantliffe. Transplant depth, irrigation, and soilless media effect on "elephant's foot" plant disorder in a hydro-phonic greenhouse sweet pepper crop. Florida Agricultural Experiment Station Journal. Series No. R-07492, 2000.
11. Kong Jong Goo, Mark W Van Iersel. Nutrient solution concentration affects shoot: root ratio, leaf area ratio and growth of subirrigated Salavia (*Salavia splendens*). Hortiscience. 2004; 39(1):49-54.
12. Kong Jong Goo, Mark W Van Iersel. Managing fertilization of bedding plants: A comparison of constant fertilizer concentration versus constant leachate electrical conductivity. Hortiscience. 2009; 44(1):151-156.
13. Libia Iris Trejo- Tellez, Fernado C Gomez-Merino. Nutrient solution for hydroponic system. Hydroponics- A Standard Methodology for Biological Researchers, 2012.
14. Lopez-Pozos R, Martınez-Gutierrez GA, Perez-Pacheco R. The Effects of Slope and Channel Nutrient Solution Gap Number on the Yield of Tomato Crops by a Nutrient Film Technique System under a Warm Climate. Hortscience. 2011; 46(5):727-729.
15. Luisa Dalla Costa, Nicola Tomasi, Stefano Gottardi, Francesco Iaccuzzo, Giovanni Cartela, Lara Manzocco *et al*. Hortscience. 2011; 46(12):1619-1625.
16. Maboko Martin M, Chritian P Du Pooy. Response of hydroponically grown cherry and fresh market tomatoes to reduced nutrient concentration and foliar fertilizer application under shed net conditions. Horti Science, 2017; 52(4):572-578.
17. Mairton G da Silva, Tales M Soares, Hans R Gheyi, Itamar de S, Oliveira, Jose A *et al*. Frequency of recirculation of nutrient solution in hydroponic cultivation of Coriander with brackish water. Revista Brasileira de Engenharia Agricola e Ambiental. 2016; 20(5):447-454.
18. Maneejantra Nuchada, Satoru Isukagoshi, Na Lu, Kanyaraft Supaibulwatana, Michiko Takagaki, Wataru Yamori. A quantitative analysis of nutrient requriments for hydroponic Spinach (*Spinacia oleracea* L.) production under artificial light in a plant factory. Journal of fertilizers and pesticide, 2016, 7-12.
19. McEvoy Miles V. Hydro-phonic and Aquaponic report, National organic programme (NOP), USDA agricultural marketing survey, 2016.
20. Nada Kazyyashi, Hiroki Nakai, Hirohito Yoshida, Masahide Isozaki, Shin Hirasuka. Hort. Res. (Japan). 2010; 9(2):203-208.
21. Nagasuga Kiyoshi, Mari Murai- Hatano, Tsuneo Kueagata. Effects of low root temperature on dry matter production and root water uptake in rice plants. Plant production science. 2011; 14(1):22-29.
22. Orsini F, Fecondini M, M.Mezzetti N, Michelon G Gianquinto. Simplified hydroponic floating systems for vegetable production in Trujillo, Peru. Acta Horticulture, 2010.
23. Pandey Renu, Vanita Jain, Singh KP. Hydroponics Agriculture: Its status, scope and limitations, 2009. www.researchgate.net/publication/259786326.
24. Pardossi A, Carmassi G, Diara C, Incrocci L, Maggini R, Massa D. Fertigation and substrate management in closed soilless culture. Report of Department of Biotechnology, University of Pisa, Pisa, Italy, 2011.
25. Park Jong-Seok, Kenji Kurata. Application of microbubbles to hydroponic solution promotes lettuce growth. Preliminary and regional reports, Hort. Technology, 2009.
26. Rafaela Felix Basilio Guimaraes, Ronaldo do Nascimenta, Daniele Ferreira de Melo, Jailton Garcia Rames, Mariana de Oliveira Pereira, Jose Alberto Ferreira Cardoso *et al*. Production of hydroponic lettuce under different salt levels of nutritive solution. Journal of Agricultural Science. 2017; 9:11.
27. Renata Nurzynska Wierdak, Ewa Rozek, Katarzyna Dzida, Barflomiej Borowski. Growth response to nitrogen and Potassium fertilization of common Basil (*Ocimum basilicum* L.) plants. Acta. Sci. Pol. Hort forumcultus. 2012; 11(2):275-288.
28. Rodriguez-Ortega WM, Martinez V, Nieves M, Camara-Zapata JM, Garcia-Sanchez F. Agronomic and physiological responses of tomato plants grown in different soilless systems to saline conditions. Peer J Preprints. 2017, 4.0.
29. Samarakoon UC, Weerasinghe PA, Weerakkody AP. Effect of Electrical Conductivity [EC] of the Nutrient Solution on Nutrient Uptake, Growth and Yield of Leaf Lettuce (*Lactuca sativa* L.) in Stationary Culture. Tropical Agricultural Research, 2006; 18(1):13-21 ISSN 1016.1422.
30. Soares Hammady R, Enio Fde, Silva FE, Geronimi F da Silva, Elvira MR, Pedrosa *et al*. Lettuce growth and water consumption in N hydroponic system using brackish water. R. bras. engineering agric. ambiental. 2015; 19(7): 636-642.
31. Sonneveld C, Wim V. Plant Nutrition of Greenhouse Crops. Springer. 2009, 431.
32. Steiner AA. A universal method for preparing nutrient solutions of certain desired composition, Plant and Soil. 1961; 15:134-154.
33. Suazo-López F, Zepeda-Bautista R, Sánchez-Del Castillo F, Martínez-Hernández J, Virgen-Vargas J, Tijerina-

Chávez L. Growth and Yield of Tomato (*Solanumly copersicum* L.) as Affected by Hydroponics, Greenhouse and Irrigation Regimes. Annual Research & Review in Biology. 2014; 4(24):4246-4258.

34. Tellez Libia, Fernado C, Gomez-Merino. Nutrient solution for hydroponic system. Hydroponics- A Standard Methodology for Biological Researchers, 2012.
35. Trang N, Schierup H, Brix H. Leaf vegetables for use in integrated hydroponics and aquaculture systems: Effects of root flooding on growth, mineral composition and nutrient uptake. African Journal of Biotechnology. 2010; 9(27).
36. Urrestarazu M. Tratado de Cultivo sin Suelo. Mundi-prensa, ISBN 84-8476-139-8, Madrid, España.
37. Vernieri P, Borghesi F, Tognoni F. Use of Bio stimulants for reducing nutrient solution concentration in floating system. Acta Hort. 2004, 718.ISHS 2006.
38. Wang Lichun, Xiaoli Chen, Wenz hong Guo, Yinkun Li, Huayan, Xuz hang Xue. Yield and nutritional quality of water spinach as influenced by hydroponic nutrient solutions with different pH adjustments. International journal of agriculture and biology, 2017, 19(4).