Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

JPP

Journal of Pharmacognosy and Phytochemistry

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2018; SP1: 1886-1891

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Hydroponic techniques: A soilless cultivation in agriculture

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Abstract
In order to expand the scope for development in agriculture in India there is a need for Hi-tech production systems. To overcome constraints like water availability, small land holdings, disease and pest incidence, problematic soils etc. one of the most favoured system or technology which is highlighted currently is “Hydroponics”. Hydroponic crop production has significantly increased in recent years worldwide, as it allows a more efficient use of water and fertilizers, as well as a better control of climate and pest factors. Furthermore, hydroponic production increases crop quality and productivity, which results in higher competitiveness and economic incomes. Among factors affecting hydroponic production systems, the nutrient solution is considered to be one of the most important determining factors of crop yield and quality. Hydroponics is always soilless culture but not all soilless culture is hydroponics. Hydroponics uses less than 1/10th - 1/5th of the water used in soil cultivation. Plants can be grown in plain nutrient solution or in sterile substrates, therefore microbe free. Basic Requirements of Hydroponics: Growing media, Nutrient solution, Temperature, Air, Supporting materials, Water, Mineral nutrient and Light. All essential nutrients are supplied to hydroponic plants in the form of nutrient solution, which consists of fertilizer salts dissolved in water. The success or failure of a hydroponic garden therefore, depends primarily on the strict nutrient management programme. Carefully manipulating the nutrient solution pH level, temperature and electrical conductivity (EC) and replacing the solution whenever necessary, will lead to a successful hydroponic garden. Though hydroponic growers can formulate their own fertilizer mixtures to prepare nutrient solutions using completely water soluble nutrients salts, a number of formulations are available in the market to choose. Therefore, select fertilizers that are compatible with each other. Many research work on Hydroponics shows great profit, and microbes free food. This method of growing our food is a more sustainable model than those currently practised. The consumer is becoming increasingly concerned over health issues, environmental issues, even water consumption cost and availability these all are drivers for the further development of hydroponic growing techniques. Thus Soilless culture is not only a solution for problematic soils but it also helps to improve the quality and quantity of agriculture produce.

Keywords: Hydroponics, Nutrient Solution, Growing media

Introduction

The word 'Hydroponics' was coined by Dr. W.F. Gericke in 1936 to describe the cultivation of edible and ornamental plants grown in a solution of water and dissolved nutrients. Hydroponic named this is new production system. Hydroponics a word derived from Greek word ‘Hydros’ (water) and ‘Ponos’ (working). Gericke originally defined hydroponics as crop growth in mineral solutions, with no solid medium for the roots. Soilless culture is a broader term than hydroponics. Hydroponics is always soilless culture but not all soilless culture is hydroponics. Hydroponics uses less than 1/10th - 1/5th of the water used in soil cultivation. Saves a lot of water. Plants can be grown in plain nutrient solution or in sterile substrates, therefore microbe free.

Hydroponics was practiced many centuries ago in Amazon, Babylon, Egypt, china and India. The “hanging Garden of Babylon” and the Aztec’s floating farms were actually prototypes of hydroponic systems. Later, when plant physiologists started to grow plants with specific nutrients for experimental purposes, they gave the name “nutriculture.” In 1929, Dr. William F. Gericke of the University of California succeeded in growing tomato vines of 7.5 m height in nutrient solutions. During 1990s home hydroponics kits became popular. During 20s hydroponics become the more organic food developer without any pollution and hazards

The available literature related to the present study has been reviewed under the following heads.

1. Basic Requirements of Hydroponics.
2. Nutrient Solution for Hydroponics and its managements.
3. Preparation of Nutrient Solution.

4. Review of Research work.

Basic Requirements of Hydroponics: These are Nutrient solution, Temperature, Air, Supporting materials, Water, Mineral nutrient, Light and most important Growing media like Saw dust, Bark, Chips, Straw, Gravel, Rockwool, Perlite, Sand and vermiculite etc.

Nutrient Solution for Hydroponics and its managements: All essential macro and micro nutrients are supplied to hydroponic plants in the form of nutrient solution, which consists of fertilizer salts dissolved in water. The success or failure of a hydroponic tehniques depends primarily on the strict nutrient management programme. Carefully manipulating the nutrient solution pH level, temperature and electrical conductivity (EC) and replacing the solution whenever necessary, will lead to a successful hydroponic. The pH of a nutrient solution from recommended pH range, the greater the odds against the success. The ideal EC range for hydroponics is between 1.5 and 2.5 dS/m. Higher EC will prevent nutrient absorption due to osmotic pressure and lower EC severely affect plant health and yield.

Preparation of Nutrient Solution: Though hydroponic growers can formulate their own fertilizer mixtures to prepare nutrient solutions using completely water soluble nutrients salts, a number of formulations are available in the market to choose. Some fertilizer salts react with each other to produce insoluble precipitations. For example, ammonium sulphate and potassium chloride form less soluble potassium sulphate in the tank. Phosphate fertilizers act problematic in the presence of high calcium and magnesium concentrations, causing precipitation of low soluble phosphates. Therefore, select fertilizers that are compatible with each other.

Review of Research work

Fakhri *et al.*, (1995) [9] experimental design reported that the largest flower diameter obtained from mixes of peat and perlite. They have been noted that media physicochemical characteristics improving because of the organic matter existence was the main reason of differences. Results showed significant difference (P≤5%) in the stem and stem neck diameter. Significantly greatest mean stem and stem neck diameter were produced in medium 7 with 0.79 and 0.58 cm respectively.

Nowak and Strojny (2004) [15] reported that the total porosity, bulk density, shrinkage water capacity and air capacity of the growing substrates had significant effects on the number and weight of fresh flowers in gerbera. Data showed that flower disc diameter influenced significantly (P≤1%) by the different media and the largest flower diameter, 11.6 cm in 7th treatment and the lowest flower diameter 10.9 cm from 1st (sand alone) is derived.

Castro *et al*. (2006) [6] observed Cluster number per plant in aquaponics was lower than in hydroponics treatments, but it increased with foliar application of elements. The highest cluster was observed in aquaponics with foliar K and Fe applications. Copper decreased cluster number in hydroponics but it had no significant effect on aquaponic grown plants. In the hydroponics, foliar application of K, Mg and Zn increased fruit number and yield of plants, but B and Cu decreased them compared to control treatments. Thus it indicates that foliar application of some elements can effectively alleviated nutrient deficiencies in tomato grown on aquaponic systems.

Ashraf, M. *et al*., (2009) [2] obsered the Growth Responses of Wheat Cultivars to Rock Phosphate in Hydroponics, The results showed that the growth behavior and P utilization efficiency of seven wheat cultivars grown in hydroponics. using rock phosphate as P source for 30 days were significantly different in biomass accumulation, P uptake and P utilization efficiency. The dry matter production of all the cultivars was significantly correlated with P uptake, which in turn correlated to the drop in the root medium pH. The ranking of wheat cultivars on the basis of dry matter yield, P uptake and P utilization efficiency was Zamindar 80 > Yecora > C 271 > WL 711 > Barani 83 > PARI 73 > Rohtas. The cultivar Zamindar 80 appeared to possess the best growth potential in P-deficient soils.

Rubio *et al*. (2010) [22] conducted experiment on Yield and fruit quality of sweet pepper in response to fertilisation with Ca^{2+} (1.5, 4 and 8) and K^{+} (2.5, 7 and 14) consisted of each three concentrations. The result found that Fruit quality were affected by the different treatment. Fruit shape index increased with the highest Ca^{2+} concentration in the root medium (0.96b). In addition, the lowest Ca^{2+} level decreased the TSS and increased the pH. Acidity increased gradually with increasing K^{+} level through the studied range of 2.5 to 14 mmol L^{-1} and a significant decrease in the maturity index with increased K^{+} level in the root medium were observed. He also found that shoot and root dry matter were significantly lower at low Ca^{2+} and at high K^{+} level in comparison with the other treatments. The decrease in shoot and root dry matter (26%) were similar for the low Ca^{2+} and high K^{+} treatments with respect to control. Therefore, higher Ca^{2+} and lower K^{+} concentration can be recommended for pepper culture.

Sindhu *et al.* (2010) [29] studied the effect of different amendments on flowering parameters of gerbera. The result observed that treatment T5 (CVP+ Samridhi) found highest flower head diameter (10.82 cm), length of flower stalk (59.2 cm), flower yield (9.27 no/plant) and vase life (13.0) followed by treatment T7 in comparison to all other treatments.

Gorbe and Calatayud, (2010) [11] observed that the uptake concentrations of Mn and Zn that were estimated by recording their removal from the recirculating NS as well as the water uptake. Both estimation methods showed that the Mn and Zn uptake concentrations by cucumber were highly affected by the levels of these micronutrients in the supplied NS, in agreement with previous results reported by (Sonneveld and de Bes 1984) [31]. The higher apparent Mn uptake concentrations than those estimated on the basis of Mn recovered from the total plant biomass may have been caused by partial immobilization of soluble Mn by oxidizing bacteria, which is a common phenomenon in aerated nutrient solutions (Bromfield, 1978) [5]. The bacteria develop rapidly as pH increases to higher levels than _5 and can oxidize an appreciable part of the applied bivalent Mn, which precipitates as manganese oxide (Sonneveld and Voogt, 1980) [30]. Thus, when the uptake concentrations of Mn were estimated by recording Mn removal from the recirculating NS, the immobilized Mn could not be distinguished from that absorbed by the plants, and thus higher values were obtained in comparison with those based on the Mn recovered from plant tissues. A decrease of soluble Mn resulting from microbial oxidation of Mn in the recirculating NS is beneficial when Mn is supplied at excessively high rates but potentially harmful if Mn is supplied at rates close to the standard uptake requirements of cucumber plants.

Roosta and Hamidpour (2011) [21] studied the Effects of foliar application of some macro and micro nutrients on tomato plants in aquaponic and hydroponic systems. The result showed that biomass gains of tomato were highest in hydroponics as compared to aquaponics and there were significant difference between cluster number but no significant difference in yield of tomato.

Shinohara *et al*. (2011) [27] studied Microbial mineralization of organic nitrogen into nitrate to allow the use of organic fertilizer in hydroponics. They observed the growth of butterhead lettuce in a hydroponic nutrient solution in which the organic nitrogen contained in fish-based soluble fertilizer was optimally mineralized into nitrate. Thus the result showed that the organic system produced significantly greater ($P < 0.05$) fresh head weight and root dry weight than in the conventional system. The leaf nitrate ion content was 35.5% lower in the organic system, and the difference was significant ($P < 0.05$). The hydroponic solutions, the next day of the start, of organic system and conventional system contained 28.82 and 35.44 mg/L K, 66.7 and 7.24 mg/L Na, 66.32 and 37.22 mg/L Ca, 0.4988 and 0.285 mg/L Fe, 10.1 and 12.6 mg/L Mg, 0.086 and 0.4048 mg/L Mn, and 0.0598 and 0.1674 mg/L B, respectively. Neither nitrate nor ammonium was detected in the hydroponic solution of either system at the end of cultivation. The ascorbic acid content of the leaves did not differ significantly ($P > 0.05$) between the two systems. It is assumed that it is attributed to larger growth of lettuce in the organic system. These results suggest that the yield and quality of butterhead lettuce in the microorganism culture system were at least as good as those in the conventional inorganic chemical system (Blom-Zandstra 2008) [4].

Khalaj *et al.* (2011) [13] studied on the Effect of Different Growing Media on the Growth and Yield of Gerbera (*Gerbera jamesonii* L.). The result found that as among the physical characteristics, aeration and water holding capacity are probably the most important factors while, among the chemical characteristics, nutritional status, and salinity level have a crucial role on plant development (Dewayne *et al.,* 2003) [8].

Wahome *et al*. (2011) [35] studied the Effects of Different Hydroponics Systems and Growing Media on the Vegetative Growth, Yield and Cut Flower Quality of Gypsophila (*Gypsophila paniculata* L.). The result showed that there was a significant ($P < 0.05$) reduction in number of shoots/plant, Cut flower stem length and Number of branches/flower in the gypsophila grown in sand in all three hydroponics system when compared to sawdust and vermiculite. However, there was no significant ($P < 0.05$) difference in number of shoots/plant, Cut flower stem length and Number of branches/flower between the plants grown in sawdust and vermiculite in all hydroponics systems. There was a more than 20 % reduction in number of shoots/plant, 30 % in cut flower stem length and 62 % in number of branches when gypsophila grown in sand. The difference in number of shoot/plant grown in sawdust and vermiculite in elevated tray and bag culture is 0.1 cm and in cut flower stem length is 5.8 cm and in number of branches/flower is 7.7 cm. Thus higher number of shoots/plant (14.3a), highest cut flower stem length (67.0a)and highest number of branches/flower (36.1a) is observed in gypsophila grown using sawdust and vermiculite in this investigation could probably be attribute to higher vegetative growth as a result of high water holding capacity and nutrient holding capacities of the medium as compared to sand.

Fazaeli *et al* (2012) [10]. Barley grain was sprouted in a still hydroponic growing chamber for 6, 7 and 8 day periods and sampled for chemical analyses, protein fractions, *in vitro* digestion and metabolisable energy (ME) determination. Productivity measured on the basis of the input-output balance of barley grain and GF yield. Results showed that CP, Ash, EE, NDF, ADF and water soluble carbohydrate (WSC) were increased whereas OM and non fiber carbohydrate (NFC) decreased ($p<0.05$) in the GF when compared with the original grain. As the growing period extended from day 6 to day 8, the CP, Ash, EE, NDF and ADF were increased but NFC and WSC reduced ($p<0.05$). The non protein nitrogen was increased but true protein decreased ($p<0.05$) in GF in comparison to barley grain, however no differences was shown among the growing periods for protein fractions. The potential (b) and rate (c) of *in vitro* gas production shown a decreasing trend ($p<0.05$) by sprouting the barley grain up to 8 days. The amount of OM and ME of GF, obtained per kg of cultivated barley grain, were lower than those of the original grain.

Tzerakis *et al*., (2013) [34] studied the Uptake of Mn and Zn by Cucumber Grown in Closed Hydroponic Systems as Influenced by the Mn and Zn Concentrations in the Supplied Nutrient Solution. The result showed that the root, stem, leaf, and fruit biomass is shown in Figure 2. The total plant biomass was reduced when the Mn or Zn concentration in the replenishment NS that was supplied to cucumber grown in a closed-cycle hydroponic system was 40 mM or higher. Similar type of result observed by Shi and Zhu (2008) [26] and Tzerakis *et al*. (2012) [33]. Nevertheless, the reduction in plant biomass was lower than 25% even at the highest Mn and Zn levels in the replenishment NS, which raised the concentrations of Mn and Zn in the recirculating NS to_270mM and 170 mM, respectively.

Asaduzzaman *et al*., (2013) [1] Studied Growing carrots hydroponically using perlite substrates, it is found that the growth, yield and quality of carrot were influenced greatly by the size of the perlite particle. Thus it observed that the suitable particle size of perlite is 0.6mm and the concentration of ‘Enshi’ nutrient solution is 100% (for first culture) or 75% (for second culture) for growing carrot hydroponically. Reuse of perlite for growing carrot may cause the media compaction, salt buildup, and other associated risks; therefore the results also suggest that properly cleaned and disinfected perlite can be reused in the succeeding crops.

Seyedi *et al.* (2013) [25] studied the Effects of Calcium Concentration under Hydroponic Conditions on Quantitative and Qualitative Growth of Lilium ‘Tresor’. The result showed that calcium concentration (6 mM) gave the highest Height of plant (cm), (75.4a), Diameter of stem (mm), (9.14a), No. of buds (8.6), Diameter of Flower’s (mm) (10.06a), Time taken to blossom (Days) (60.7a) and vase life (Days) (10.27a) as compared to other concentration. The results gathered from the experiments carried out, showed that the increase of calcium concentration in the nutrition soluble solution had a direct effect on the increase in height, both in blooming stem and general height of the plant. It became clear that by increasing calcium concentration in nutrition nourishment, the diameter of the flowers and stem thickness increases significantly. Apparently by increasing the calcium concentration in nutrition soluble solution, the calcium concentration within the aerial organs also increases (Robicheux, 2008) [20]. Thus in hydroponics maximum concentration of calcium increases the growth parameters as compared traditional cultivation and enhances the quantitative and qualititative character of Lilium ‘Tresor’.

Marinou *et al*. (2013) [14] studied the Use of sawdust, coco soil and pumice in hydroponically grown strawberry. The result revealed that organic matter (and as a consequence the organic carbon content) was increased in Saw-100compared with Coc-100. The most substrates particle size was under 2 mm. Adding pumice into the sawdust substrate altered the negative properties of aeration and balance water content of the latter. An increased EC (averaged 3.08 mS/cm) was observed in Coc-100 and affected substrate EC was reported in different mixtures. Saw-100 affected medium acidity (revealed – 4.71 pH) and contributed to the increased amount of N, K and P while no changes were revealed for Na content. Additionally, Coc-100 added nutrient amount of K and P, but also Na. Cultivation of bell peppers (cv. Sardana) performed better on perlite, a 'dry' substrate, than on coir which seems to have a higher demand for oxygen supply in the root zone, when grown at two levels of CO2 (Savidov 2005) [24]. Thus result show the putative use of organic medium i.e. Sawdust on top of the widely used coco soil as substrate medium in strawberry culture. The performance of plants grown on Pum-Saw (50-50), followed by the Coc-Saw (50-50) and then by Coc-Pum (50-50) is markedly influenced by the media and the alteration of physicochemical properties (such as porosity, water content and air capacity) of raw material and hence the air and water balance in the root environment.

Dayananda & Wahundeniya (2014) [7] studied the Effect of different hydroponic systems and media on growth of lettuce (*Lactuca sativa*) under protected culture. The result found that the root length, leaf area, fresh plant weight, dry weight and yield obtained from plants grown under 3 different hydroponic systems. It is clear that the aggregate system has shown the most promising results. Thus the result were significantly higher than the other two systems. Longer root (17.5 cm) and heavier root mass would have absorbed more nutrients resulting larger area (752.3 cm^2) and higher plant weight (46.8 g). The highest yield was also recorded in the aggregate system (2340 g/m^2). This system had a good aeration than the other two and it had wider spacing provided dark condition for root development. The result indicates that growing media have shown significantly variable results for growth parameters. The coir dust (T1) showed the most effective results giving higher values for root length (16.9 cm) and total leaf area (727.05 cm2) while it was placed second in fresh weight (40.2 g) and dry weight (1 g) which were not significantly different from the treatments which showed the highest values. While all other treatments which which were blended with coir dust and partially burnt paddy husk and partially burnt paddy husk alone showed higher values. However the treatments with tea refuse (T4) and its mixture gave the lowest values. Thus it shows that the refuse is not suitable as a growing media, while coir dust alone or mixed with partially burnt paddy husk or burnt paddy husk alone make good growing media for lettuce cultivation under control environments.

Treftz *et al*. (2015) [32] studied the Comparison between hydroponic and soil systems for growing strawberries in a greenhouse. The result showed that the total yield of the soil-grown strawberries was 70 strawberries. The hydroponic strawberries had a 17% higher yield compared to the soil grown strawberries. In the totality of strawberries grown both conventionally and hydroponically, the standard deviation was large, indicating a wide variation of weights in all harvested strawberries; however, standard deviation in weight was smaller comparatively between hydroponic strawberries (3.0 vs. 3.7) and soil-grown strawberries. Thus by hydroponics sizes of fruit is larger of straw berries. Plant survival rates for both growing conditions are shown in Hydroponic plants had a higher survival rate at 80% compared to the soil-grown strawberries, which survived less than 50%. Although both growing systems received identical integrated pest management treatments, the soil plants suffered more and the pests thrived in the soil-grown strawberries, especially the aphids and spider mites. This can be attributed to increased beneficial bacteria and microbes that pests thrive on in soil conditions (Resh & Howard, 2012) [18]. The results found in this study suggest that using hydroponic systems on a large scale has the potential to reduce pesticide usage. Accomplishing this would provide the farmer with higher economic benefits.

Barbosa *et al.,* (2015) [3] studied the Comparison of Land, Water, and Energy Requirements of Lettuce Grown Using Hydroponic *vs.* Conventional Agricultural Methods. The result found that while the hydroponic production of lettuce results in higher yields and more efficient water use, the controlled environment from which the hydroponic system produces its higher yields exhibits a higher energy demand. Higher yields of hydroponics result from the controlled environmental conditions maintained within the hydroponic greenhouse, which allow for continuous production year round. These conditions also promote a reduction in the number of days required for each harvest cycle, allowing for multiple crops per year. This benefit of hydroponic production is not unique to lettuce alone, but will vary depending on the operational parameters under which the crop is grown. Similarly, most hydroponic systems will utilize water more efficiently than conventional farming. Lettuce has shallow roots, but is primarily irrigated through flood furrow irrigation in south western Arizona. Water not quickly absorbed by the roots is lost to percolation. Increases in the use of low-flow and more-targeted irrigation techniques could lower the overall water use of conventional farming. (Sanchez *et al.* 2014) [23].

Putra and Yuliando (2015) [16] observed that Soilless cultivation is intensively used in protected agriculture to improve control over the growing environment and to avoid uncertainties in the water and nutrient status of the soil. Recently the type of soilless culture transformed from open to close-loop system. This system is known for better result in water use efficiency, while maintaining the quality of the yield and the specific purpose of soilless culture specifically in close-loop system and how substrate nutrition produces the better quality of the yields.

Rai. *et al*., (2016) [17] studies comparative on growth and yield parameters of transplanted wheat (*Triticum aestivum* L.) with seedling produced in hydroponics system vis-a-vis conventional cultivation. The result showed that there were significant differences between two systems for plant height (cm), number of days of panicle emergence and yield/acre (kg).Maximum plant height (30.1cm) and yield/acre (1828.6 kg) was recorded in 7 days hydroponics system followed by 29.9 cm of plant height in 10 day hydroponics. Thus hydroponics system proved more convenient than the traditional propagation system using peat sand mixture and mineral fertilizers (Ritter *et al* 2001) [19].

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