Chapter 1

Influence of Soilless Culture Substrate on Improvement of Yield and Produce Quality of Horticultural Crops

Md. Asaduzzaman, Md. Saifullah,
AKM Salim Reza Mollick, Md. Mokter Hossain,
GMA Halim and Toshiki Asao

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/59708

1. Introduction

Soilless culture is the modern cultivation system of plants that use either inert organic or inorganic substrate through nutrient solution nourishment. Possibly it is the most intensive culture system utilizing all the resources efficiently for maximizing yield of crops and the most intense form of agricultural enterprises for commercial production of greenhouse vegetables [1-3]. Several studies suggested soilless culture in the greenhouse as an alternative to traditional field production for high-value vegetable crops [4-7]. This protected cultivation system can control the growing environment through management of weather factors, amount and composition of nutrient solution and also the growing medium. Therefore, quality of horticultural crops grown through soilless culture improves significantly compared to conventional soil culture [8,9]. This artificial growing system provides plants with mechanical support, water and mineral nutrient for higher growth and development. Over the years, hydroponics has been used sporadically throughout the world as a commercial means of growing both food and ornamental plants. Now at days, it has also been used as the standard methodology for plant biological researches in different disciplines [10]. Various modification of pure solution culture has been taken place over time throughout the world. Primarily, gravel or sand was used in soilless culture system to provide plant support and retain mineral nutrient and water. Afterward, several substrates have been evolved due to their unique properties for holding moisture, aeration, leaching or capillary action, and reuse potentiality. Soilless growing media are easier to handle and it may provide better growing environment (in terms of one or more aspects of plant growth) compared to soil culture [11,12]. Organic substrates includes sawdust, coco peat, peat moss, woodchips, fleece, marc, bark etc. whereas, inorganic substrate of natural

origin are perlite, vermiculite, zeolite, gravel, rockwool, sand, glass wool, pumice, sepiolite, expanded clay, volcanic tuff and synthetically produced substrates are hydrogel, foam mates (polyurethane), oasis (plastic foam) etc. [13-18]. Various raw materials have been used to produce growing media for vegetable production throughout the world. Capabilities of compost for use in soilless culture of horticultural crops have also been confirmed in a number of studies [19,20]. Oil palm frond compost has a great potential to be utilized for the improvement of soilless culture system. It is successfully used to control plant diseases [21-24]. In addition, plant nutrients from oil palm frond compost are released slowly over a long period of time and are less likely to leach out of the media.

Although successful cultivation of different vegetables and ornamentals crops in soulless culture with bark source have been reported [25-27], phytotoxicity from phenolic compounds may be extracted from the substrate [28,29]. Therefore, it is evident that at present, utilization, standardization of nature of raw materials used for soilless growing media is diverse in origin [30]. Each substrate has its specific properties and usually differs from others. These differences between growing media have to be considered for successful soilless cultivation of horticultural crops. In this instance Gruda *et al*. [31] suggested the activity of microorganisms must be evaluated in comparing peat and its substitutes, such as bark, wood fiber substrate, paper and straw substrates. In order to build up own body protein components, these microorganisms need mineral nitrogen, which they gain from the available nitrogen content in the substrate. Therefore, nitrogen would not be readily available for the plants in soilless substrate which in turns may lead to potential quality losses of the produce [31].

In recent years, the use of soilless culture has increased significantly throughout the world [2, 32]. More than 60% of the vegetable greenhouses in the Netherlands cultivated using rockwool media but it is costly and difficult to dispose because it is not biodegradable and environmental friendly [26,33]. Perlite which is less expensive than rockwool has been used as soilless culture substrate around the world for successful production of vegetables, fruits, and cut flowers in the greenhouse [2,34]. Similarly, zeolite has also the potentiality as soilless media for its unique properties. Zeolite crystal alumina silicates have negative charges, which is balanced by one or two valence of positively charged cations [35]. It has high water absorption, retention and releasing capability, high cation exchange capacity, and high buffering ability of pH change [36]. It has been found that due to its higher cation exchange capacity, water and nutrient holding ability; yield and fruit quality of tomato increased greatly [37]. Soilless culture of gerbera produced higher yield in perlite/zeolite (1:1) substrate than other mixtures, due to its improved aeration and water retention ability [38]. Another substrate is coconut coir has a great demand by the ornamental industries especially in The Netherlands and Canada [39], and more recently, the product has been marketed as a substitute for rockwool in the greenhouse vegetable industry. There are many indigenous and locally available soilless culture substrates used by different countries and similarly produced synthetic substrate suitable for growing system of specific crops. Use of different locally available and inexpensive soilless substrates with no pollution limitations but with adequate physical and chemical properties has been suggested worldwide. Mixture of different substrates also been used for higher growth and yield of several crops around the world [40-43]. Soilless culture in bags, pots or

http://dx.doi.org/10.5772/59708

trays with light weight medium is the simplest, easiest and economical way of growing crops. The most common types of growing media in container based system are peat-lite, a mixture of bark and wood chips [44]

The problems in agricultural land use such as soil exhaustion, pest infestation or chemical interference are increasing greatly due to intensive cropping, injudicious application of pesticides or continuous monoculture [45-49]. In this regard, soilless culture can avoid problems with monoculture of plants in the same land for years [50]. It can provide several major advantages in the management of both plant nutrition and plant protection. The main reason of need for soil to soilless culture for horticultural crops is the problem related to proliferation of soil borne pathogen in the soil cultivation. Research studies reported that commercial production of greenhouse vegetables with soilless media adopted to reduce economic losses caused by soil-borne pathogens [51-53]. While other researchers reported that soilless culture can provide more efficient use of water and fertilizers [54,55], reduce root diseases [56], and facilitate cultivation of crops in areas where normal cultivation is not possible [57]. Thus, soil has been replacing by many organic and inorganic substrates, since they are disease and pest free inert material capable of holding required sufficient moisture and can be reused year after year. The physical and hydraulic properties of soilless culture substrate is better that those of soil medium. In soil culture plant root get higher water availability just after irrigation which cause lower oxygen content to be used by plant root and micro flora but in substrates optimum aeration is possible due to its leaching or pulling capacity by capillary action. Water application is several times higher in tomato (4 times) and lettuce (5 times) under conventional cultivation system compared to hydroponics [58]. Root development and nutrient absorption is less in plants grown in soil but soilless substrates especially inorganic origin can hold adequate moisture, nutrient through their surface charge and also allow profuse root hair formation for efficient absorption. However, root volume is restricted in container based substrate culture. This limitation has several beneficial effects such as limited supply of nutrient is possible in soilless substrate culture [59, 60] and also increases the root to root competition since there are more roots per unit volume of medium.

Substrate culture under protective agriculture has minimized the discharge of fertilizer and pesticide residues into the natural environment such as freshwater reservoir. However, there are several observations to be considered for successful crop grown in soilless substrate culture. The limited volume of substrate and water availability can cause rapid decrease in water and mineral nutrient status. Therefore, changes in amount of solution, its electrical conductivity (EC), and pH should be monitored regularly for efficient use of water and nutrients. In soilless substrate mineral nutrient usually supplied as ionic form and thus when plant exposed to low relative humidity, it lose water by transpiration leading to evaporation of water from the medium and plant tissue. This transpiration and evaporation can lead to salt build-up in the substrate due to improper management.

Suitability of different substrates in successful vegetable establishment and their effect on growth, yield and produce quality have been extensively investigated by many researchers around the world. However, only few researches have been conducted for improvement of horticultural crop quality in different substrates. Recent reviews suggested that changes in

quality parameters of horticultural crops influenced by the use of growing substrate [152] and present a comprehensive overview of the effect mineral soil, inorganic and organic growing media on the growth, development, yield and quality of vegetable crops grown under greenhouse condition [13]. This chapter aims mainly to describe the importance of soilless culture for enhancing quality production of horticultural crops, improving produce quality beneficial to human health, economics of reutilization of once used substrates and also the prospect of soilless culture in improving and maximizing crop yield.

2. Improvement of horticultural produce quality through soilless hydroponics

Horticultural produce from soilless culture have better qualities than those from conventional soil-based cultivation [8,61-63]. Although the exact differences between qualities of vegetables grown in soil or hydroponics are difficult to determine [64] but soilless culture in greenhouse may be an alternative to soil culture for high-value vegetables crops including tomatoes, peppers, cucumbers, lettuce etc. In a study, Massantini *et al*. [9] found better taste, uniformity, color, texture and higher nutritional value in fruits grown in soilless culture than in soil cultivation methods. Similarly, it was also found that tomatoes produced in the nutrient film technique system were firmer and richer in vitamin C than those grown from soil-based plants. It also contained more sugar, acid and sodium, resulting in a distinct taste. Vegetables from organic substrate culture in greenhouse and poly tunnels are in high demand. Thus, in order to increase the qualities of horticultural produce appropriate fertilizer application, especially nitrogen and phosphorus along with growing substrate prepared from organic materials are suggested [65]. Several studies showed that in general plants harvested from soilless culture had a lower dry weight and leaf area, however, significantly higher productivity were observed at the end of harvest [66]. In this culture system, high concentration of nitrogenous fertilizer enhance the vigorous growth, which reduce the penetration of light intensity to the whole canopy due to huge foliage and thus reduce the accumulation of ascorbic acid in shaded parts. Enhanced growth of plants due to nitrogenous fertilizer may also have a relative dilution effect in plant tissue. Therefore, excess use of nitrogenous fertilizer increases the concentration of nitrate in plant tissue and simultaneously decreases that of ascorbic acid, it may have double negative effect on the quality of plant foods [67].

In a study it was found that, potassium concentration in plant parts may vary for growing seasons (spring or autumn) and also growing systems [68]. It was reported that tomato plant grown in aeroponics gave higher concentrations of P, K and Mg and lower concentrations of Ca than nutrient film techniques [69]. Substrate culture found to be affected greatly increasing mineral contents in plants especially due to luxurious nutrient uptake during vegetative growth [70]. Fruit quality of tomato is greatly influenced by potassium mineral nutrition. It positively affects the contents of soluble sugars, vitamin E, carotenoids in fruits but its luxurious absorption may also negatively affect the uptake of magnesium, calcium, and boron from nutrient solution [71-73]. This antagonistic interaction of potassium with calcium leads to decrease in concentration of calcium in the medium. As a result, a typical symptom generally

http://dx.doi.org/10.5772/59708

appears known as blossom-end rot disease on tomato fruit which lower the quality greatly [74]. Despite application on the same medium, various substrates like sand, mine material of volcanic origin, rockwool, wood fiber, peat and coir showed significant differentiation in the nutrient content [75-78].

Soilless culture has been extensively used in tomato cultivation both in commercial and experimental basis. Many researchers has compared, standardized and otherwise applied various substrates in tomato culture in soilless hydroponics. In general soilless culture reported to increase the tomato fruits quality greatly around the world. It has been found that organic growing media produced higher yield and number of fruit than conventional growing system in greenhouse tomato production [13,79]. Many studies also suggested that tomato fruits grown in organic substrates had higher dry matter, vitamin C, and nitrogen compared to rockwool [80,81]. Similarly, these properties were improved in rape straw substrate along with peat and pine bark compared to rockwool [82]. The quality and quantity of tomato fruit in organic media found better than inorganic media [83] and when it grown in different substrates the highest amount of total yield and number of fruits were harvested from perlite + rice hull while fruits with highest total soluble solids were from coco-peat substrate [84]. Tomato plants grown in perlite and zeolite mixture substrate (2:1) produced greater fruit size, total soluble solid, sensorial qualities and also highest dry matter of fruit [85] and it was also reported that cucumber plants grown in nutrient film technique gave higher fruit quality than plants grown in perlite culture [86]. Fruit qualities such as fruit weight, fruit firmness, total soluble solids, titratable acidity, ascorbic acid and carotenoids were found to be influenced by the soilless substrate used, while they had not any effect on EC, pH and dry matter content.

Utilization of rockwool and perlite in soilless hydroponic culture results in higher yield compared to other inert materials [84]. However, it also reported that tomato grown in substrate prepared from cutting pieces of rye and wheat straw [17] or slabs made of shredded rye straw [88] yielded higher than that from rockwool cultivation. The tomato plants that grown in perlite and zeolite with 2:1 ratio had best distribution of fruit size, total soluble solid and sensorial quality and highest dry matter of fruit was found in perlite substrate [85]. Research results also suggested that addition of maize to perlite and pumice could improve properties of inorganic substrates for tomato soilless culture, leading to higher yields and better quality fruit [87]. Most of the sensory characteristics such as redness of surface skin, firmness, crispness, sourness, sweetness, tomato aroma and overall impression after chewing were varied greatly due to differences in variety, followed by maturity, harvest time and EC but type of growing medium either soil or rockwool had no or little effect. However, for the characteristics related to texture (crispness and firmness), the ranking was harvest time, EC, growth medium, maturity and variety, with soil-grown tomatoes being slightly but significantly softer than the rockwool grown tomatoes [89]. Higher EC values in the growing medium may cause decrease in fruit yield but on the other hand, it improves the taste by increasing dry matter, soluble solids, and titratable acidity [90]. It has been found that salinity of the water improves the quality of tomato [91]. In soilless culture, increase the EC value of irrigation water or that of nutrient solution increase the acidity [92], the soluble sugars [93,94], and dry matter percentages of fruits [92,95] while decrease the size of fruits in cherry tomato [96].

Maize stems having light weight and less costly can be used as substrate in soilless culture which contains readily available organic matters [97]. In another study, tomato fruit quality characteristics such as mean fruit weight, fruit firmness, total soluble sugars, titratable acid, carotenoids, and ascorbic acid were affected differently by the use of maize shredded stems, perlite and pumice substrates and among them maize shredded stem substrate resulted in greater fruit firmness compared to perlite, pumice substrate [98]. Customer tests indicated that firmness and flavor are important criteria for high quality tomato, where typical tomato flavor depends on the ratio between sugar and acid [99]. Higher sugar and organic acid content improves the quality of tomato fruits [100]. Amount of citric acidity in tomato fruits was found as higher or similar in tuff or sand substrate compared to soil medium [101]. In another study with lettuce, Siomos *et al.* [102] found that soilless culture results in higher citric acid percentage compared to soil culture. However, fruit size and quality characteristics also showed no significant difference within substrate of coco-peat, rockwool and masato [103]. Harvesting time of tomatoes had influence on the quality parameters as in September harvest produced higher dry matter and carotenoids content than that of June harvested fruits. However, June harvested fruits were characterized by a higher total sugars content, pH of juice and soluble solids content [104]. In this regards, it is mentionable that tomatoes sensory quality mainly determined by sugar content which represent the major components of soluble solids [105].

After tomato lots of research works have been conducted on soilless substrate for its influence on improvement of growth, yield and quality of pepper. Growing media composed of soil, peat, perlite, sand and pumice significantly affect the yield, fruit weight, ascorbic acid values and total soluble solids of pepper cultivars [106]. The highest early yield was obtained in pepper plants grown on the peat medium compared to perlite, pumice, sand and soil [106]. Schnitzler *et al.* [107] observed better plant growth, fruit yield and quality in bell pepper (*Capsicum annuum* L.) grown in wood fiber substrate. Recent studies showed that plants grown on peat media had higher ascorbic acid content, total soluble solids, fruit number per plant and yield than its mixture with perlite or sand [108]. Peat contains higher potassium than its mixture substrates [108] and it has been reported that growing media with high potassium could increase the vitamin C content in plants [109]. Green peppers were grown in mixture of substrates such as vermiculite + sand, peat + perlite and rockwool showed that peat + perlite had most influence on its growing traits and yield [110]. However, when perlite compared with rice husk substrates it was found that plants grown in rice husk had higher growth and yield in the later [111]. In another study, differential response of growing substrates were reported and they showed significant effect on plant height, number of leaves, chlorophyll index and total yield per plant [112].

In strawberry better growth has been reported in coir than that in perlite substrate [113]. In another study, the influence of different substrates on the growth of strawberry was reported as peat, finpeat or finpeat + perlite in Camaros and Fern cultivars [114]. Jafarnia *et al.* [115] reported total soluble solid were influenced by substrate and cultivars and fruit qualities such as vitamin C and titratable acidity were highest in rice husk substrate. Caso *et al*. [116] used rice husks and pumice with different ratios in column system for the production of strawberry and they recommended that 100% rice husks substrate influence majority of measured traits.

http://dx.doi.org/10.5772/59708

It also found that content of phenolic compounds, especially anthocyanin depend on substrate pH [117] while Lopes da Silva *et al.* [118] reported total anthocyanin would range between 200 and 600 mg kg^{-1} fresh weight. From research results it is evident that soilless culture substrate affect the quality of strawberry and desirable fruit production is greatly depends on suitable choice of substrate and cultivars [119]. They found that highest total anthocyanin content and titratable acidity in Camarosa cultivar in vermiculite + perlite + coco-peat; the highest antioxidant in Camarosa and Mrak cultivars in substrate of Sycamore pruning waste and coco-peat + perlite; and the highest total soluble solids in Selva cultivar in vermiculite + perlite + coco-peat substrate. Strawberries grown in greenhouses with different soilless growing media also showed their impact on phytochemical and nutritional composition [120]. Agricultural cropping systems greatly influence the productivity and yield of crops. It has been reported similar [121,122] or even higher [123] yield for organic corps than conventional soil cultivation. Minerals such as calcium and magnesium concentrations were observed higher in organic and low input soil system but soilless growing system produced fruits with higher firmness in the green stage which is related to higher flesh thickness of fruits [124].

Rockwool substrate can be used to produce melons hydroponically [125,126] but costs would be higher than other substrate materials and its disposal is very difficult [127,128]. Recently, Rodriguez *et al.* [129] investigated different combinations of media (coarse and medium perlite) and containers (polyethylene bags and plastic pots) for hydroponic production of 'Galia' muskmelons (*Cucumis melo* L.) and found that fruit yield and quality were not affected by any combination of media and containers. In recent studies it was found that sweeter cantaloupes or rock melon fruits harvested in plants grown in empty fruit branch media than coconut dust as soilless media [130]. Effect of different substrates has been studied on growth, yield and quality of watermelon in soilless culture [131]. Quality and quantity of watermelon fruit had not any significant difference between different substrates evaluated [131]. Influence of peat substrate and its mixture with perlite or zeolite on the quality of cucumber seedlings and photosynthesis parameter has investigated [132]. It has been suggested that the highest yield of cucumber fruit obtained from cocopeat substrate than other substrates like perlite-cocopeat (50-50, v/v), perlite-cocopeat-peatmoss (50-20-30 and 50-30-20, v/v) and other growth indices such as stem diameter, biomass, fruit's number, fruit size and fruit diameter were greater in cocopeat [133]. In another study, it was showed that total soluble solids along with growth indices such as yield, biomass weight, shoot diameter, plant height, root weight, and leaf area index of cucumber plant were significantly higher in date-palm substrate than soil media but generally had no significantly difference as compared with perlite substrate [134].

In a recent study, carrots were grown successfully in hydroponics using perlite substrate [135]. It was found that carrot plants grown in 0.6 mm perlite supplied with 100% nutrient solution produced significantly higher root yield compared to larger perlite particles and higher concentrations of nutrient solution. Carrots grown in 0.3 mm perlites produced shorter roots, wider near the proximal end and whitish in the distal end due to excessive water content causing oxygen deficiency. It was found that seedlings grown in peat substrate are higher, have bigger leaf area than seedlings grown in peat-perlite, peat-zeolite substrate, but in leaves and roots dry matter accumulation was less. Higher tuber yield in potato grown in hydroponics

compared to conventional system was reported [136]. This higher tuber yield was attributed by the uninterrupted and optimal nutrient and water supply in hydroponic culture.

Soilless culture has predominant influence on the floriculture industries and can provide means of best quality flowers production throughout the year. In roses industry, higher yield and best quality of stems are entirely depends on physico-chemical properties of growing substrates. It was found that incorporation of rice hulls and press mud in traditional substrate found to be improved the growth and quality indices and increased flower yield of *Rosa hybrids* L. cvs. 'Kardinal', 'Anjlique' and 'Gold Medal' [137]. Fascella and Zizzo [138] studied that soilless cultivation of roses in perlite or coconut coir dust increased yield and stem quality. This might be related to the higher water holding capacity and cation exchange capacity of coconut coir, suggesting this organic substrate is one of the alternatives to peat for hydroponic culture. The highest quality of cut flowers of gypsophila in terms of stem length and number of branches per flower were obtained from plants grown in sawdust growing medium under soilless hydroponics with bag culture [139]. High quality cut flowers of oriental hybrid lily were obtained in solid medium hydroponics when compared to mist culture system [140]. It was also observed that broken chaff substrate induced higher quality lily cut flowers as compared with chaff, hydro-ball or carbonized chaff substrate. Hsu *et al.* [141] grew *Oncidium* orchids in rockwool, sphagnum peat moss and mixed medium containing crushed stone, bark and charcoal. They found that pseudo bulbs mass, root activity, cut flower qualities in terms of flower length, floret number and number of shoots were higher in rockwool compared to other media. However, little difference in yield and quality could be attributed due to types of soilless medium used under adequate management practice and environmental conditions [126,142]. The amount of nutrients in both organic and inorganic substrates changes during active vegetative growth of plants and its indication may be appeared in the leaves. Thus frequent analysis of substrate, at least once a moth is important for successful cultivation under soilless cultivation [76,78,143].

3. Production of specialty crops providing human health benefits through soilless hydroponics

The world's population increased greatly in last few decades. The improvement of living standard in many countries increased with the great demand for high value crops, off season supply and high quality products. Therefore, quality of life (QOL) of people increased considerably. In this regard, protected agriculture which is a labor intensive industry can produce higher amount of food for the increased population of the world. The efficiency and quality of the agricultural produce can be increased through the modifications of the environmental controls, management of culture systems and use of technological innovations. The greatest advantage of soilless culture is that it allows direct control of the nutrient solution, possible to modify composition and concentration to achieve predictable results in relation to dry matter content, nitrate content or other organoleptic and structural features of the crop produce [144]. Thus, physical, chemical and biological characteristics of the substrates must correlate with water and fertilizer supply, climatic conditions and plant demand [145-149]. In

addition, production or biosynthesis of bioactive compounds will largely be depending upon the manipulation of these characteristics. Phenolic acids are important bioactive compounds having antioxidant activity. Tomato fruits are the good source of phenolics usually taken by human through their daily diet [150,151]. However, it was found that growing medium (standard mineral wool slabs or coconut fibre slabs) or harvest term (September or June) had no influence on the phenolic acids content in the tomato fruits [104]. Other studies also showed that the qualitative traits of the products obtained from soilless culture appear to be substantially similar to the products coming from conventional cultivation [152,153]. Soilless culture may improve the parameters related to nutritional, organoleptic and hygienic-sanitary characteristics [152,153] but some aspects of vegetable quality reported to be clearly improved, such as phytosanitary residues, enhanced organoleptic characteristics and longer shelf life [154]. Special dietary requirements are also sometime fulfilled e.g., enrichment of and/or increase in selenium [155], iron [156], omega 3 [157], and lowering the nitrate [158], and potassium content [159].

Soilless substrate originated from organic materials would improve the product quality with health promoting substance. Many studies indicated that higher nutritional value and higher content of biologically active compounds in the agricultural products from organic farming [160-162]. However, other studies reported that effect of cultivation method disappears when the results converted to absolutely dry matter [163,164]. In most studies it also found that vitamin C content in organic fruits is higher than that of conventional tomatoes [163-165]. In conventional cultivation methods, tomato plants absorb easily assailable nitrogen from the substrate. A large concentration of this macro element results in increased synthesis of protein components and proteins, which adversely affect the synthesis of carbon-based compounds such as vitamin C. Therefore, plant products from organic farming are higher in vitamin C compared to conventional system [166,167]. Organic growing system also influence the nutritional value and phenolic compound content in tomato [168] and a two years study showed that organic tomato had higher ratio of reducing sugar/organic acids, more total sugars, vitamin C, total flavonoids, 3-quercetin rutinoside, quercetin-3-*O*-glucoside, myricetin, chlorogenic acid and kaempferol content than convention fruits.

Research reports revealed that tomato flavor is related to the balance between total soluble sugars and organic acids in the fruits [169]. It has been found that potassium fertilization had positive effect on fruits sugar and acid content [170], therefore, soilless substrate containing higher amount of potassium will increase the sweet flavor of fruits. Potassium supplied from the growing media also influences the antioxidant content of tomatoes, which is considered as beneficial for human health. On the other hand vitamin C is a health-promoting substance with antioxidant properties, which in turn play efficient role in preventing the conversion of nitrate to nitrite in plant tissue and within the human body [171]. Amount of nitrogen absorbed is an important factor influencing the vegetables quality and the way in which absorbed nitrogen is utilized in plant metabolism either as nitrate or nitrite form in the edible plant tissue [172]. These factors can be better managed in hydroponics through management and supply of nutrient solution composition in the small volume of rooting or culture medium.

Fast growing fruits and leafy vegetables had great potential for enrichment of minerals, bioactive compounds and health promoting substances. Commercial cultivation of these crops for a specific dietary requirement can be possible in order to meet the demand of such type of people. Cultivating leafy vegetables in a floating system is the easiest and cheapest means of production, since this system shows high water and nutrient use efficiency with low environmental impact [173]. This cultivation system produced acceptable yield and good control quality parameters in baby leaf species. Siomos *et al.* [174] found that plants from a soilless culture had higher nitrate, total nitrogen, phosphorus and potassium content compared to plants harvested from soil culture. Fruits and vegetables grown in soil contaminated with environmental toxicant or pollutant from industrial effluent or heavy pesticide application have higher mineral contents along with toxic heavy metals and if accumulated in their tissue will impose potential health risk to human [175-177]. Surface soil act as toxic chemical filters that may absorb and retain toxicants from waste water and other effluents. However, due to continuous accumulation of these pollutants and changes in soil pH, the capacity of soil to retain toxic elements reduces and thus surface soil permit these elements to pass into ground water or available for plant uptake [178]. Micronutrients and heavy metals are a group of non-biodegradable elements with the tendency of bioaccumulation in living systems causing serious health problem [179-182]. Moreover, research results reported that some heavy metals such as Cu, Cr, Ni, Zn, Fe etc. at low doses are essential for plants but at high doses cause metabolic disorders and growth inhibition especially Pb and Ni [183,184].

Industrial effluent often contains considerable quantities of heavy metals and other substance that may be toxic to people but beneficial for horticultural crops. Therefore, it is imperative that before effluent can be used for commercial production of vegetables and fruits, it must be determined whether there is or not accumulation of heavy metals [185]. In a study, application of recycling water in broccoli caused an increased yield but it also resulted in enhanced heavy metals in tissues [186], therefore, when applying recycle water, the amount of heavy metal must be considered and managed to a minimal level. In this regard, Emongor *et al.* [187] reported that applying secondary treated sewage effluent enhanced yield of tomato when compared to the plants irrigated with tap water. Recycle water is the easily available source of nutritional supplement necessary for crop growth and thus it has reported to an increase in agricultural crop productivity [186,188,189]. Although wastewater and sewage effluents had beneficial effect on horticultural crops, it contains a significant amount of trace elements and other toxicant that are harmful to human [190]. Previously, an enhanced amount of minerals with applying recycle water has been reported [191]. Similarly, it has been reported that with application of recycle water in cabbage the amount of mineral caused an increase in tissue and resulted in enhanced yield [192]. Moreover, from the economic viewpoint, recycle water in irrigation of crops under proper agronomic and water management practices may provide higher yields and save additional cost of water and fertilizer [189].

Now a day's expensive pesticides application in controlling pests and diseases is a prerequisite for successful production of horticultural crops. Pesticide residues in the agricultural products often cause health hazards. Therefore, growing demand of high quality of fruits and vegetables with minimal or without pesticide residue is desirable to the local consumer and also for

http://dx.doi.org/10.5772/59708

commercialization. In this case, soilless culture is a good alternative method of quality crop production [193]. Therefore, soilless culture techniques could be applied to grow selected and popular local horticultural crops with the application of food safety standards at a reasonable price [194]. In addition, injudicious use of nitrogenous fertilizers lead to the production of green vegetables with higher NO_3^- content, which considered to be cancerous to human health. Apart from soil culture, solution culture also produces vegetables with higher NO_3^- and this hazardous ion could be reduced to a greater extent through eco-organic soilless culture system [195]. In regards to NO_3^- content of fruit, the highest value was found in organically grown green peppers and the lowest values were observed in red peppers regardless of organic, low-input and soilless systems [124].

4. Reuse of soilless culture substrate with an economic view point and environmental issues

Substrate culture is considered to be main soilless technique for commercial scale production of horticultural crops. However, it has disadvantage of disposal of growing substrate after crop cultivation. In general, hydroponics is claimed to involve a high initial capital investment and need of technical knowledge for complicated cultivation procedures. However, these problems could be resolved by using locally available materials in simplified methods and equipments. For example, farmers in Japan built their own hydroponic production system using local material which much cheaper than purchasing [196]. Reviews of several research works on the use of substrate in soilless culture showed differential influences on growth, yield and quality of crops. In addition to cultivars and horticultural management practices, growing media had great influence on the yield and fruit quality of greenhouse grown tomato [197]. It was found that plants grown in perlite produced higher total marketable yield that plants grown in either rockwool or pine bark. However, the initial costs to grow greenhouse tomato in perlite were higher than rockwool and were the lowest in pine bark. Replacing perlite substrate at every growing season of tomato was found costly [197]. Continued culture with perlite substrate without proper reconditioning, desalination and disinfection may cause medium compaction, salt built up and pest infection [198-200]. Thus increased salt concentration can reduce fruit size [201], decrease fruit number [202] or can negatively impact root and shoot growth of tomato plants [203]. Therefore, reuse techniques are necessary for sustainable soilless production with lower inputs. Recent researches suggested that perlite can be recycled and used for many years, thus reduce production cost without any negative impact on crop yield [198,199]. If rockwool substrates can be steam sterilized and reused once and then it must be disposed because of fiber break-down during steam sterilization and handling [204]. Therefore, a significant cost is associated with the disposal of rockwool substrate [205]. Disposal of used substrate create environment hazardous in the 1980s, thereafter several research efforts has been taken on modern horticultural techniques to comply with ecological mandates and bio-stability of soilless substrates [206]. As a result several new organic growing

media have been suggested by many researchers around the world based on renewable raw materials.

In substrate culture, continuous recirculation of nutrient solution is difficult to maintain. Low sterilization techniques are necessary, thus rockwool slabs with drainage to waste are the most common system especially in the Netherlands [207]. In soilless culture, salt e.g., Na^+ and Cl^- accumulation in the growing media is common which may exert negative effects on salt sensitive crops [208]. Therefore, collection and sterilization technique of drainage nutrient solution are to be developed for reuse [209]. In recent years, a number of investigations have been taken on the water and nutrient balance in greenhouse-grown crops [210]. It has been clearly shown that the large excesses of water and minerals absorption lead to the emissions of N in larger extent and P to a lesser extent to the environment. Therefore, recirculation of once used nutrient solution is imperative for economic crop production hydroponically. In this regards, high EC and nutrient level in the soilless medium are necessary to meet the crop requirements at the high rates obtained under protected cultivation [211] which in turns will enhance product quality grown therein [212]. On the other hand, in soil-bound crops surface water is often used, and since it contains rather high salt concentrations, leaching is necessary to prevent salinity problems [213]. Therefore, the need of leachation, sterilization and reutilization could be the process sustainable crop production through soilless culture system. However, the cost of fertilization was found to be insignificant compared with the total production cost in greenhouse cropping [214]. Crop cultivation in reused substrates revealed both positive and negative responses compared to fresh ones. Some researchers found reduction of crop yield and/or produce quality in re-used substrate [215], while others reported no or minimal differences between new and reused substrate [216-221].

Reuse of substrate is an important option for environmental management of growing media and of soilless culture. It may increase crop profitability, although substrate costs generally constitute a small fraction of the total production costs of greenhouse and nursery crops [222]. However, breakdown of substrate materials can exert detrimental effect on crop for repeated use several years. Physical and chemical modification of both organic and inorganic substrates may also occur after one or two growing cycles, and number of growing cycles of a substrate depends on its nature and the type of crops grown. Research findings showed that generally inorganic substrates tend to last longer for example; polyurethane upto 10 years [223,224], perlite upto 3 years [225], rockwool upto 3 years [226]; and organic substrates have a shorter life upto 2-3 years due to minor biostability [227,228]. Thus, physical stability of the growing medium becomes an important issue in maintaining favorable growing conditions for the whole period [229-231]. It has been suggested that substrate volume could be reducing until 25%, without yield reduction, if irrigation scheduling is adapted to the lower water buffer. Decision on prolonged the use of substrate should be taken using new quick test for assessing the physical, chemical and phytopathological conditions before the start of new cultivation [232]. Among the soilless substrate perlite has good traits for soilless cultivation because of its high water absorption ability, high water efficiency, reuse potentiality and decrease cost of production [233].

http://dx.doi.org/10.5772/59708

5. Future prospects of soilless culture for maximizing yield of horticultural crops

Soilless culture technique has been used successfully in the production of difficult to grown plants. It has great opportunities to explore the inabilities of production constraints involving environmental controls. Modification of culture methods and culture environment can lead to a sustainable crop production desirable for human beings. In this regards, hydroponic production of medicinal and aromatic herbs showed a new insight towards the mass production of these plants leading to high secondary metabolites yields and qualities [234-236]. Soilless culture of medicinal herbs has many valuable advantages such as high yields, clean cultivation, year round production and production of drugs with minimum herbicide and pesticide residues [237,238]. Adequate supply of water and mineral nutrients increase the absorption and subsequently higher dry matter production both in aerial and underground parts of medicinal plants are the main advantages of substrate culture compared to field grown counterparts [237,239-241]. Therefore, successful soilless hydroponics of high value medicinal plant could be promising for pharmaceutical and food industries on meeting their high demands for *Chrysanthemum balsamita* (L.) Baill. raw materials [242].

In Southern Tunisia, the application of geothermal water in soilless culture using sand as substrate found to be much more appropriate than perlite and stone pumice substrates. In sands, plants growth was faster and gave higher marketable yield with improved fruit quality having higher acidity and sugar content [243]. Transpiration influences transport and translocation of calcium in the plant body. It has been found that, nutrient and transpiration are both important in preventing blossom-end rot disease in tomato in soilless culture. Thus, mineral nutrient level i.e., EC value should be maintain for improvement of produce quality. Studies revealed that potassium and EC have positive effects on quality of vegetable crops grown in hydroponics. On the contrary, low EC found to promote quality of cut flower. Further investigation are necessary to determine the prolong reuse of the substrates and their mixtures.

The need for soilless culture arose from plant protection issues with soil-borne pathogens and environmental regulations against groundwater pollution with industrial effluents, nitrate and pesticides. Soilless substrates either having organic or inorganic ingredients have been used as for finding suitable growing media for horticultural crop production. The types of raw material used vary according to their domestic availability in the world. Raw materials variations in different substrate influence the plant growth and development directly and/or indirectly. Thus selection of ideal substrate from various materials is imperative for productivity of each crop [244]. Lots of substrates evolved for horticultural crops production with their cultural guidelines. From them only suitable or adapted cultural guidelines will benefits the grower in successful cultivation for his produce.

Author details

Md. Asaduzzaman[1*], Md. Saifullah[1], AKM Salim Reza Mollick[1], Md. Mokter Hossain[2], GMA Halim[1] and Toshiki Asao[3]

*Address all correspondence to: asadcbt@yahoo.com; asadcbt@bari.gov.bd

1 Olericulture Division, Horticulture Research Centre, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur, Bangladesh

2 Department of Horticulture, Faculty of Agriculture, Bangladesh Agricultural University, Mymensingh, Bangladesh

3 Department of Agriculture, Faculty of Life and Environmental Science, Shimane University, Kamihonjo, Matsue, Shimane, Japan

References

[1] Dorais M, Papadopoulos A, Gosselin A. Greenhouse tomato fruit quality. Horticultural Reviews 2001;26: 239-319.

[2] Grillas S, Lucas M, Bardopoulou E, Sarafopoulos S, Voulgari M. Perlite based soilless culture systems: Current commercial applications and prospects. Acta Horticulturae 2001;548: 105-114.

[3] Jensen M. Food production in greenhouses. In: Plant Production in Closed Ecosystems: The International Symposium on Plant Production in Closed Ecosystems. Kluwer, Dordrecht, The Netherlands. 1997; p.1-14.

[4] Blank C. Specialty process for specialty products. The Grower Magazine, March 1999; p.28-30.

[5] Cantliffe DJ, Shaw NL, Jovicich E, Rodriguez JC, Secker I, Karchi Z. Passive ventilated high-roof greenhouse production of vegetables in a humid, mild winter climate. Acta Horticulturae 2001;559: 195-201.

[6] Paradossi A, Malorgio F, Campiotti C, Tognoni F. A comparison between two methods to control nutrient delivery to greenhouse melons grown in recirculating nutrient solution culture. Scientia Horticulturae 2002;92: 82-95.

[7] Schroder FG. Alternative vegetables grown in hydroponic systems. Acta Horticulturae 1999;481: 213-220.

[8] Xu HL, Gauthier L, Gosselin A. Effects of fertigation management on growth and photosynthesis of tomato plants grown in peat, rockwool and NFT. Scientia Horticulturae 1995;6(1-2): 11-20.

[9] Massantini F, Favilli R, Magnani G, Oggiano N. Soilless culture-biotechnology for high quality vegetables. Soilless Culture 1988;4(2): 27-40.

[10] Asao T. Hydroponics - A Standard Methodology for Plant Biological Researches. Rijeka: InTech; 2012.

[11] Bilderback TE, Warren SL, Owen Jr. JS, Albano JP. Healthy substrates need physicals. HortTechnology 2005;15: 747-751.

[12] Mastouri F, Hassandokht MR, Padasht Dehkaei MN. The effect of application of agricultural waste compost on growing media and greenhouse lettuce yield. Acta Horticulturae 2005;697: 153-158.

[13] Olle M, Nagouajio M, Simos A. Vegetable quality and productivity as influenced by growing medium: A Review. Zemdirbyste Agriculture 2012;99(4): 399-408.

[14] Dorais M, Menard C, Begin E. Risk of phytotoxicity of sawdust substrate for greenhouse vegetables. Acta Horticulturae 2007;761: 589-594.

[15] Ehret DL, Helmer T. A new wood fibre substrate for hydroponic tomato and pepper crops. Canadian Journal of Plant Science 2009;89(6): 1127-1132.

[16] Mahamud S, Manisah MD. Preliminary studies on sago waste as growing medium for tomato. Acta Horticulturae 2007;742: 163-168.

[17] Nurznski J. The yield of greenhouse tomato grown in straw and rockwool. Folia Horticulture 2006;18(2): 17-23.

[18] Sevgican A. Protected vegetable growing. II. Ege Univeristy. Agriculture Faculty. Izmir, Turkey, 1999b; No. 526.

[19] Khalighi A, Padasht Dehkaei MN. The effect of media produced by tree bark, tea waste, rice hull and azolla as a substitute for peat, on growth and flowering marigold (*Tagetes patulta* L. Golden Boy). Iranian Journal of Agricultural Science 2000;31(3): 557-565.

[20] Urrestarazu M, Salas MC, Padilla MI, Moreno J, Elorrieta MA, Carasco GA. Evaluation of different composts from horticultural crop residue and their uses in greenhouse soilless cropping. Acta Horticulturae 2002;549: 147-152.

[21] Cotxarreara L, Trillas-Gay MI, Steinberg C, Alabouvette C. Use of sewage sludge compost and *Trichoderma asperellum* isolates to suppress *Fusarium* wilt of tomato. Soil Biology and Biochemistry 2002;34: 467-476.

[22] Coventry E, Noble R, Mead A, Whipps JM. Suppression of Allium white rot (*Sclerotium cepivorum*) in different soils using vegetables wastes. European Journal of Plant Pathology 2005;111: 101-112.

[23] Siddiqui Y, Sariah M, Ismail MR, Rahmani M, Ali A. Bio-efficiency of compost extracts on the wet rot incidence, morphological and physiological growth of okra (*Abelmoschus esculentus* [(L.) Moench.]). Scientia Horticulturae 2008;117: 9-14.

[24] Souleymane BK, Antoine D, Russell JT, Hani A, Tyler JA. Suppressive effect of non-aerated compost teas on foliar fungal pathogens of tomato. Biological Control 2010;52: 167-173.

[25] Cantliffe DJ, Funes J, Jovicich E, Paranjpe A, Rodriguez J, Shaw N. Media and containers for greenhouse soilless grown cucumbers, melons, peppers, and strawberries. Acta Horticulturae 2003;614: 199-203.

[26] Shaw NL, Cantliffe DJ, Funes J, Shine Ill. Successful Beit Alpha cucumber production in the greenhouse using pine bark as an alternative soilless media. HortTechnology 2004a;14: 289-294.

[27] Wilson GCS. Tomato production in bark substrates. Acta Horticulturae 1984;150: 271-276.

[28] Politycka B, Wojcik-Wojtkowiak D, Pudelski T. Phenolic compounds as a cause of phytotoxicity in greenhouse substrates repeatedly used in cucumber growing. Acta Horticulturae 1985;156: 89-94.

[29] Worrall RJ. The use of composted wood waste as a peat substitute. Acta Horticulturae 1978;82: 79-86.

[30] Gruda N, Prasad M, Maher MJ. Soilless Culture. In: Lal R. (ed.) Encyclopedia of Soil Science. Taylor & Francis (Marcel Dekker), Inc., New York; 2005.

[31] Gruda N, von Tucher S, Schenitzier WH. N-immobilization of wood fiber substrates in the production of tomato transplants (*Lycopersicon lycopersicum* (L). Karst. Ex Farw). Journal of Applied Botany 2000;74:32-37

[32] Garzo EC, Soria C, Gomez-Guillanmon ML, Fereres A. Feeding behavior of *Aphis gossypii* on resistant accessions of different melon genotypes *Cucumis melo*. Phytoparasitica 2002;30: 129-140.

[33] Beniot F, Ceusterman N. A decade of research on ecologically sound substrates. Acta Horticulturae 1995;408: 17-29.

[34] Tyson RV, Hochmuth RC, Lamb EE, Hochmuth GH, Sweat MS. A decade of change in Florida's greenhouse vegetable industry: 1991-2001. Proceedings of Florida State Horticultural Society, 2001;113: 280-282.

[35] Mumpton FA. Uses of natural zeolites in agriculture and industry. Proceedings of Natural Academy of Science, USA; 1999;96: 3463-3470.

[36] Allen ER, Ming DW. Recent progress in the use of natural zeolites in agronomy and horticulture. Nature of Zeolites 1995;93: 477-490.

[37] Dijedidi M, Grasopoulos D, Maloupa E. The effect of different substrates on the quality of f. Carmello tomatoes (*Lycopersicon escullentum* Mill.) grown under protection in a hydroponic system. Chaiers Options Mediterraneans 1997;31: 379-383.

[38] Issa M, Maloupa E, Gerasopoulos D. Effects of the substrate on yield and quality of two gerbera varieties grown under protection. Chaiers Options Mediterraneans 1997;31: 365-369.

[39] Kaveri Agri-Care. Processed coir pith (coco-peat) for export. Kaveri Agri-Care Pvt. Ltd., Bangalore, India; 26 January 2004.

[40] Donnan R. Hydroponics around the world. In: Practical Hydroponics & Greenhouses. July/August 1998.

[41] Seymour G. Review of commercial hydroponic crop production system. In: Commercial Hydroponics in Australia, A Guide for Growers, Pro-Set Pty Ltd, Hobart; 1993.

[42] Raviv M. The future of composts as ingredients of growing media. Acta Horticulturae 2011a;891: 19-32.

[43] Raviv M. Suppressing soil-borne disease of container-grown plants using composts. Acta Horticulturae 2011b;893: 169-181.

[44] Boodley JW, Sheldrake Jr. R. Cornel peat-lite mixes for commercial plant growing. International bulletin 43. New York State College of Agriculture and Life Science; 1977.

[45] Asaduzzaman M, Mondal FM, Ban T, Asao T. Selection of ideal succeeding crops after asparagus, taro, and beans replanting field in seedling growth bioassay. Allelopathy Journal 2013;32(2): 1-22.

[46] Hegde R, Miller DA. Allelopathy and autotoxicity in alfalfa: Characterization and effects of preceding crops and residue incorporation. Crop Science 1990;30: 1255-1259.

[47] Komada H. The occurrence, ecology of soil-borne diseases and their control. Takii Seed Co. Ltd. Kyoto, Japan 1988; p.1-3.

[48] Takahashi K. The replant failure of vegetables. Research Reports of National Research Institute of Vegetable and Tea Science, Japan 1994;pp. 87-99 (In Japanese).

[49] Sevgican A. Protected vegetable growing. I. Ege University. Agriculture Faculty, No. 528. Izmir, Turkey; 1999.

[50] Alan R. Characteristics of some of the growth media used in greenhouse. Turkey 5. Greenhouse Symposium, October 17-19, Izmir, Turkey; 1990: p.401-410.

[51] Gullino ML, Garibaldi A. Influence of soilless cultivation on soilborne diseases. Acta Horticulturae 1994;361: 341-353.

[52] Louvet J. The relationship between substrates and plant diseases. Acta Horticulturae 1982;126: 147-152.

[53] Riviere LM, Caron J. Research on substrates: State of the art and need for the coming 10 years. Acta Horticulturae 2001;548: 29-41.

[54] Jensen MH. Hydroponics. HortScience 1997;32: 1018-1021.

[55] Schwarz M. Soilless culture management. Springer-Verlag, New York, 1995.

[56] Reed DW. Water media and nutrition for greenhouse crops. In: Reed DW (ed.) Growing media: Types and physical/chemical properties. Ball Publishing, Batavia, Ill; 1996. p.93-122.

[57] Jensen MH. Greenhouse hydroponic industry status reports: Hydroponics worldwide. Acta Horticulturae 1999;481: 719-729.

[58] Hassall & Associates. Hydroponics as an agricultural production system: A Report for the Rural Industries Research and Development Corporation. RIRDC publication, no. 01/141; RIRDC project, no. HAS-9A. 2001. p.72.

[59] Dubik SP, Krizek DT, Stimart DP. Influence of root zone restriction on mineral element concentration, water potential, chlorophyll concentration, and partitioning of assimilate in spreading Euonymus (*E. kiautschovica Loes*, 'Sieboldina'). Journal of Plant Nutrition 1990; 677-699.

[60] Bar-Tal A. The significance of root size for plant nutrition in intensive horticulture. In: Renge Z. (ed.) Mineral Nutrition of Crops: Fundamental Mechanisms and Implications. New York: Haworth Press, Inc.; 1990. p.115-139.

[61] Varis S, Altay H. The most suitable and new method for soilless growing in Turkey: Perlite culture. First Perlite Symposium. Turkish Agriculture, Izmir, Turkey; 1992; p. 185.

[62] Abak K, Celikel G. Comparison of some Turkish originated organic and inorganic substrates for tomato soilless culture. Acta Horiculturae 1994; 366: 423-427.

[63] Alan RA, Zulkadir A, Padem H. The influence of growing media on growth, yield and quality of tomato grown under greenhouse conditions. Acta Horticulturae 1994;366: 429-436.

[64] Schnitzler WH, Gruda N. Quality issues of greenhouse production. Acta Horticulturae 2003;614: 663-674.

[65] Voogt W, de Visser PHE, van Winkel A, Cuijpers WJM, van de Burgt GJHM. Nutrient management in organic greenhouse production: Navigation between Constraints. Acta Horticulturae 2011;915: 75-82.

[66] Frezza D, Leon A, Logegaray V, Chiesa A, Desimone M, Diaz L. Soilless culture technology for high quality lettuce. Acta Horticulturae 2005;697:43-48.

[67] Lee SK, Kader AA. Preharvest and postharvest and postharvest factors influencing vitamin C content of horticultural crops. Postharvest Biology and Technology 2000;20(3):207-220.

[68] Singer SM, El-Tanahy AMM, El-Behairy UA, Abu El-Samad EH. Growth and productivity of cantaloupe plants grown under different soilless culture systems. Journal of Applied Sciences Research 2013;9(8): 5294-5302.

[69] Yang W, Chung S, Kim Y. Comparative studies on the physioecological and morphological adaptations of greenhouse tomato grown in aeroponics and nutrient film technique. III. Characteristics of physioecological adaptations. Journal of Korean Society of Horticultural Science 1990;31(3): 226-237.

[70] El-Behairy UA. The effect of levels of phosphorus and zinc in the nutrient solution on macro and micronutrients uptake and translocation in cucumber (*Cucumis sativus* L.) grown by the nutrient film technique. PhD thesis. London University 299P. UK, 1994.

[71] Gent PPN. Effect of nitrogen and potassium supply on yield and tissue composition of greenhouse tomato. Acta Horticulturae 2004;644: 369-375.

[72] Caretto S, Parente A, Serio F, Santamaria P. Influence of potassium and genotype on vitamin E content and reducing sugar of tomato fruits. Horticultural Science 2008;43: 2048-2051.

[73] Ramirez SLF, Diaz SFR, Muro EJ. Relation between soilless tomato quality and potassium concentration in nutritive solution. Acta Horticulturae 2012;947: 215-221.

[74] Benko B, Borosic J, Poljak M, Osvald J. Incidence of tomato blossom-end rot at different calcium levels. Acta Horticulturae 2012;927: 385-392.

[75] Nurzynski J. Effect of different fertilization levels on yielding of greenhouse tomato grown on sand, peat or rockwool growth media. Vegetable Crops Research Bulletin 2005;63: 101-107.

[76] Choi J, Ahn J, Ku J. Growth and nutrient uptake of tomato plug seedling influenced by elevated blendingrate of perlite in coir and peatmoss substrates. Horticulture Environment and Biotechnology 2007;48(5): 270-276.

[77] Miccolis V, Candido V, Lucarelli G, Castronuovo D. Cherry tomato yield on two different solid growing media. Acta Horticulturae 2007;761: 573-579.

[78] Komosa A, Kleiber T, Pirog J. Contents of macro- and micronutrients in root environment of greenhouse tomato grown in rockwool and wood fiber depending on nitrogen levels in nutrient solutions. Acta Scientiarum Polonorum Hortoroum Cultus 2010;9(3): 59-68.

[79] Rippy FMJ, Peet MM, Louws FJ, Nelson PV. Orr DB. Sorensen KA. Plant development and harvest yield of greenhouse tomatoes in six organic growing systems. HortScience 2004;39(2): 223-229.

[80] Kowalczyk K, Gajc-Wolska J, Marcinkoswska M. The influence of growing medium and harvest time on the biological value of cherry fruit and standard tomato cultivars. Vegetable Crop Research Bulletin 2011a;74: 51-59.

[81] Kowalczyk K, Gajc-Wolska J, Radzanowska J, Marcinkoswska M. Assessment of chemical composition and sensory quality of tomato fruit depending on cultivars and growing conditions. Acta Scientiarum Polonorum Hortorum Cultus 2011b;10(4): 133-140.

[82] Nurzynski J. Yield and quality of greenhouse tomato fruit grown in rape straw substrates. Acta Scientiarum Polonorum Hortorum Cultus 2013;12(1): 3-11.

[83] Permuzic Z, Bargiela M, Garci A, Rendina A. Calsium, iron, potassium, phosphorous and vitamin C content of organic and hydroponic tomatoes. Hort Science 1998;33(2): 255-257.

[84] Inden H, Torres A. Comparison of four substrates on the growth and quality of tomatoes. Acta Horticulturae 2004;644: 205-210.

[85] Djedidi M, Gerasopoulos D, Maloupa E. The effect of different substrates on the quality of F. Carmello tomatoes grown under protection in a hydroponics system. Cahiers Option Mediterraneans's 2001;p.31.

[86] Fernández-Trujillo JP, Sánchez C, Obando J, Gómez MD, Mercader JM. Quality of greenhouse fruit grown on perlite substrate or nutrient film technique. Acta Horticulturae 2004;633: 229-236.

[87] Tzortzakis NG, Economakis CD. Impact of the substrate medium on tomato yield and fruit quality in soilless cultivation. Horticultural Science (Prague) 2008;35: 83-89.

[88] Dysko J, Kowalczyk W, Kaniszewski S. The influence of ph of nutrient solution on yield and nutritional status of tomato plants grown in soilless culture system. Vegetable Crop Research Bulletin 2009;70: 59-69.

[89] Thybo AK, Bechmann IE, Brandt K. Integration of sensory and objective measurements of tomato quality: quantitative assessment of the effect of harvest date as compared with growth medium (soil *versus* rockwool), electrical conductivity, variety and maturity. Journal of the Science of Food and Agriculture 2005;85: 2289-2296.

[90] Tuzel JH, Tuzel Y, Sul A, Elterz RZ. Effect of EC level on the nutrient solution on yield and fruit quality of tomato. Acta Horticulturae 2001;559: 587-592.

[91] Dorais M, Papadopulos AP, Gosselin A. Influence of electric conductivity management on greenhouse tomato yield and fruit quality. Agronomie 2001;21: 367-383.

[92] Adams P, Ho LC. Effects of constant and fluctuating salinity on the yield, quality and calcium status of tomatoes. Journal of Horticultural Science 1989;64: 725-732.

[93] Petersen K, Willumsen J, Kaack K. Composition and taste of tomatoes as affected by increased salinity and different salinity sources. Journal of Horticultural Science & Biotechnology 1998;73: 205-215.

[94] Sato S, Sakaguchi S, Furukawa H, Ikeda H. Effects of NaCl application to hydroponic nutrient solution on fruit characteristics of tomato (*Lycopersicon esculentum* Mill.). Scientia Horticulturae 2006;109: 248-253.

[95] Adams P. Effects of increasing the salinity of the nutrient solution with major nutrients or sodium chloride on the yield, quality and composition of tomatoes grown in rockwool. Journal of Horticultural Science 1991;66: 201-207.

[96] Serio F, De Gara L, Caretto S, Leo L, Santamaria P. Influence of an increased NaCl concentration on yield and quality of cherry tomato grown in posidonia (*Posidonia oceanica* (L.) Delile). Journal of the Science of Food and Agriculture 2004;84: 1885-1890.

[97] Tzortzakis NG, Economakis CD. Shredded maize stems as an alternative substrate medium - Effect on growth, flowering and yield of tomato in soilless culture. Journal of Vegetation Science 2005;11: 57-70.

[98] Tzortzakis NG, Economakis CD. Impact of the substrate medium on tomato yield and fruit quality in soilless cultivation. Horticultural Science (Prague) 2008;35: 83-89.

[99] Vesseur WP. Tomato tasting and consumer attitude. Acta Horticulturae 1990; 259: 83-89.

[100] Davies J., Hobson G. The constituents of tomato fruit-the influence of environment, nutrition and genotype. In: McGlasoon W. CRC Critical Reviews in Food Science and Nutrition. Taylor and Francis 181;15: 205-281.

[101] Fandi M, Al-Muhtaseb JA, Hussein MA. Yield and fruit quality of tomato as affected by the substrate in an open soilless culture. Jordan Journal of Agricultural Sciences, 2008;4(1): 65-72.

[102] Siomos AS, Beis G, Papadopoulou PP, Barbayiannis N. Qulaity and composition of lettuce (cv. Plenty) grown in soil and soilless culture. Acta Horticulturae 2001;548: 445-450.

[103] Luitel B, Adhikari PB, Yoon CS, Kang WH. Yield and fruit quality of tomato (*Lycopersicon esculentum* Mill.) cultivars established at different planting bed size and growing substrate. Horticulture Environment and Biotechnology 2012;53(2): 102-107.

[104] Mazur KZ, Gajewski M, Metera AM, Wtulich JA, Marcinkowska MM. Effect of growing medium and harvest term on yield and several quality traits of two cultivars of 'Cherry' tomatoes. Notulae Botanicae Horti Agrobotanici 2012;40(2): 197-202.

[105] Islam MS, Matsui T, Yoshida Y. Carbohydrate content and the activities of sucrose synthase, sucrose phophate synthase and acid invertase in different tomato cultivars during fruit development. Scientia Horticulturae 1996;65: 125-136.

[106] Padem H, Alan R. The Effects of some substrate on yield and chemical composition of peppers under greenhouse conditions. Acta Horticulturae 1994;366: 445-451.

[107] Schnitzler WH, Sharma AK, Grud NS, Heuberger HT. A low-tech hydroponics system for bell pepper (*Capsicum annuum* L.). Acta Horticulturae 2004;644: 47-52.

[108] Gungor F, Yildirim E. Effect of different growing media on quality, growth and yield of pepper (*Capsicum annuum* L.) under greenhouse conditions. Pakistan Journal of Botany 2013;45(5): 1605-1608.

[109] Aydemir O, Ince F. Plant nutrition. Dicle University, Diyarbakir, Turkey, Publication no. 2; p.653

[110] Majdi Y, Ahmadizadeh M, Ebrahimi R. Effect of different substrates on growth indices and yield of green peppers at hydroponic cultivate. Current Research Journal of Biological Sciences 2012;4(4): 496-499.

[111] Maaswinkel R, Gunadi N, Lembang I. Improving sweet pepper yields in Indonesia. Fruit and Vegetable Technology 2009;9(4): 14-15.

[112] Albaho M, Bhat N, Abo H, Tomas B. Effect of three substrates on growth and yield of two cultivars of *Capsicum annuum*. European Journal of Scientific Research 2009;28: 233-227.

[113] Lopez- Madina J, Perablo A, Flores F. Closed soilless system growing: A sustainable solution to strawberry crop in Huelva (Spain). Acta Horticulturae 2008;649: 213-215.

[114] Ercisli S, Sahin U, Esitken A, Anapali O. Effects of some growing media on the growth of strawberry cvs. 'Camarosa' and 'Fern'. Acta Agrobotanica 2005;58: 185-191.

[115] Jafarnia S, Khosrowshahi S, Hatamzadeh A, Tehranifar A. Effect of substrate and variety on some important quality and quality characteristics of strawberry production in vertical hydroponic system. Advances in Environment and Biology 2010;4(3): 360-363.

[116] Caso C, Chang M, Rodriguez-Delfin A. Effect of growing media on the strawberry production in column system. Acta Horticulturae 2009;843: 373-380.

[117] Schmitzer V, Stampar F. Changes in anthocyanin and selected phenolics in Korcrisett rose flowers due to substrate pH and foliar application of sucrose. Acta Horticulturae 2009;870: 89-96.

[118] Lopes da Silva F, Escribano-Bailon MT, Joaquin Perez Alonso J, Rivas-Gonzalo JC, Santos-Buelga C. Anthocyanin pigments in strawberry. LWT- Food Science and Technology 2007;40: 374-382.

[119] Ameri A, Tehranifar A, Davarynejad GH, Shoor M. The effect of substrate and cultivar in quality of strawberry. Journal of Biological and Environmental Science 2012; 6(17): 181-188.

[120] Tulipani S, Mezzetti B, Capocasa F, Bompare S, Beekwilder J. Antioxidants, phenolic compounds, and nutritional quality of different strawberry genotypes. Journal of Agriculture and Food Chemical 2008;56: 696-704.

[121] Chellemi DO, Rosskopf EN. Yield potential and soil quality under alternative crop production practices for fresh market pepper. Renewable Agriculture and Food Systems 2004;19: 168-175.

[122] Poudel DD, Horwath WR, Lanini WT, Temple SR, Bruggen AHC. Comparison of soil N availability and leaching potential, crop yields and weeds in organic, low-input and conventional farming systems in northern California. Agriculture Ecosystem and Environment 2002;90: 125-137.

[123] Curuk S, Sermenli T, Mavi K, Evrendilek F. Yield and fruit quality of watermelon (*Citrullus lanatus* (Thumb.) Matsum. & Nakai.) and melon (*Cucumis melo* L.) under protected organic and conventional farming systems in a Mediterranean region of Turkey. Biological Agriculture and Horticulture 2004;22: 171-183.

[124] Flores P, Hellin P, Lacasa A, Lopez A, Fenoll J. Pepper mineral composition and sensory attributes as affected by agricultural management. Journal of the Science of Food and Agriculture 2009;89: 2364-2371.

[125] Fukuda N, Anami Y. Substrate and nutrient level: Effects on the growth and yield of melon '*Cucumis melo*' in soilless culture. Acta Horticulturae 2002;588: 111-117.

[126] Guler HG, Olympios C, Gerasopoulos D. The effect of the substrate on the fruit quality of hydroponically grown melons *Cucumis melo* L. Acta Horticulturae 1995;379: 261-266.

[127] Bohme M. Evaluation of organic, synthetic and mineral substrates for hydroponically grown cucumbers. Acta Horticulturae 1995;401: 209-217.

[128] Schwarz M. Soilless culture management. Springer-Verlag, New York, 1995.

[129] Rodriguez JC, Cantliffe DJ, Shaw NL, Karchi Z. Soilless media and containers for greenhouse production of 'Galia' type musk melon. HortScience 2006;41: 1200-1205.

[130] Zulkarami B, Ashrafuzzaman M, Mohd Razi I. Morpho-physiological growth, yield and fruit quality of rock melon as affected by growing media and electrical conductivity. Journal of Food, Agriculture & Environment 2010;8(1): 249-252.

[131] Yetisir H, Sari N, Aktas H, Karaman C, Abak K. Effect of different substrates on plant growth yield and quality of watermelon grown in soilless culture. Agriculture and Environmental Science 2006;1(2): 113-118.

[132] Jankauskiene J, Brazaityte A. The influence of various substratum on the quality of cucumber seedlings and photosynthesis parameters. Scientific Works of the Lithuani-

an Institute of Horticulture and Lithuanian University of Agriculture. Sodininkyste Ir Darzininkyste 2008;27(2): 285-294.

[133] Alifar N, Mohammadi Ghehsareh A, Honarjoo N. The effect of growth media on cucumber yield and its uptake of some nutrient elements in soilless culture. Journal of Science and Technology of Greenhouse Culture. Isfahan University of Technology 2010;1: 19-25.

[134] Ghehsareh AM, Hematian M, Kalbasi M. Comparison of date-palm wastes and perlite as culture substrates on growing indices in greenhouse cucumber. International Journal of Recycling of Organic Waste in Agriculture 2012;1(5): 1-4.

[135] Asaduzzaman M, Kobayashi Y, Mondal MF, Ban T, Matsubara H, Adachi F, Asao T. Growing carrots hydroponically using perlite substrates. Scientia Horticulturae 2013;159: 113-121.

[136] Willis CR. Hydroponics-the Solution to the Food Problem. 2009. http://www.androidpubs.com/Chap02.htm,10/07/09].

[137] Ahmad Z, Khan MA, Qasim M, Zafar MS, Ahmad R. Substrate effects on growth, yield and quality of *Rosa hybrida* L. Pakistan Journal of Botany 2012;44(1): 177-185.

[138] Fascella G, Zizzo GV. Effect of growing media on yield and quality of soilless cultivated rose. Acta Horticulturae 2005;697: 133-138.

[139] Wahome PK, Oseni TO, Masarirambi MT, Shongwe VD. Effects of different hydroponics systems and growing media on the vegetative growth, yield and cut flower quality of gypsophila (*Gypsophila paniculata* L.). World Journal of Agricultural Sciences 2011;7(6): 692-698.

[140] Ryota T, Kazunori M, Musao T, Kazuyoshi S. Studies on the hydroponics of oriental hybrid lily. Journal of the Niigata Agricultural Research Institute 2002;5: 65-74.

[141] Hsu JH, Lin YH, Lin RS. Effect of cultural medium and hydroponics culture on growth and flower quality of *Oncidium* grower Ramsey. Acta Horticulturae 2007;761: 489-493.

[142] Raja Harun RM, Hall DA, Szmidt RAK, Hitchon GM. Melon cultivation in organic and inorganic substrates. Acta Horticulturae 1991;294: 105-108.

[143] Nurzynski J, Michalojc Z, Jarosz Z. Mineral nutrient concentration in potting media (rockwool, peat, sand) and growth of tomato. Vegetable Crops Research Bulletin 2001;55: 45-48.

[144] Elia A, Frezza D, Fraschina A, Trinchero G, Moccia S, Leon A. Preharvest factors and fresh cut vegetables quality. Acta Horticulturae 1999;481: 267-271.

[145] Gruda N, Schnitzler WH. Suitability of wood fiber substrates for production of vegetable transplants. I. Physical properties of wood fiber substrates. Scientia Horticulturae 2004a;100: 309-322.

[146] Gruda N, Schnitzler WH. Suitability of wood fiber substrates for production of vegetable transplants. II. The effect of wood fiber substrates and their volume weights on the growth of tomato transplants. Scientia Horticulturae 2004b;100: 333-340.

[147] Gruda N, Schnitzler WH. The effect of water supply on bio-morphological and plant-physiological parameters of tomato transplants cultivated in wood fiber substrate. Journal of Applied Botany 2000a;74: 233-239.

[148] Gruda N, Schnitzler WH. The effect of water supply of seedlings cultivated in different substrates and raising systems on the bio-morphological and plant-physiological parameters of lettuce. Journal of Applied Botany 2000b;74: 240-247.

[149] Gruda N, Schnitzler WH. Wood fiber substrates as a peat alternative. European Journal of Wood and Wood Products 2006;64: 347-350.

[150] Luthria DL, Mukhopadhyaya S, Krizek DT. Content of total phenolics and phenolic acids in tomato (*Lycopersicon esculentum* Mill.) fruits as influenced by cultivar and solar UV radiation. Journal of Food Composition and Analysis 2006;19: 771-777.

[151] Martinez-Valverde I, Periago MJ, Provan G, Chesson A. Phenolic compounds, lycopene and antioxidant activity in commercial varieties of tomato (*Lycopersicon esculentum* L.). Journal of the Science of Food and Agriculture 2002;82: 323-330.

[152] Gruda N. Do soilless culture systems have influence on product quality of vegetables? Journal of Applied Botany and Food Quality 2009;82: 141-147.

[153] Santamaria P, Valenzano V. La qualita degli ortaggi allevati senza suolo. Italus Hortus 2001;8: 31-38.

[154] Cefola M, Pace B, Buttaro D, Santamaria P, Serio F. Postharvest evaluation of soilless-grown table grape during storage in modified atmosphere. Journal of Science of Food and Agriculture 2011;91: 2153-2159.

[155] Pedrero Z, Madrid Y, Camaraj C. Selenium species bioaccessibility in enriched radish (*Raphanus sativus*): a potential dietary source of selenium. Journal of Agriculture and Food Chemistry 2006;54: 2412-2417.

[156] Inoue K, Kondo S, Adachi A, Yokota H. Production of iron enriched vegetables: effect of feeding time on the rate of increas in foliar iron content and foliar injury. The Journal of Horticultural Science and Biotechnology 2000;75: 209-213.

[157] Palaniswamy UR, McAvoy RJ, Bible BB. Omega-3-fatty acid concentration in *Portulaca oleracea* is altered by nitrogen source in hydroponic solution. Journal of the American Society for Horticultural Science 2000;125: 190-194.

[158] Santamaria P, Elia A, Gonnella M, Parente A, Serio F. Ways of reducing rocket salad nitrate content. Acta Horticulturae 2001;548: 529-537.

[159] Asao T, Asaduzzaman M, Mondal MF, Tokura M, Adachi F, Ueno M, Kawaguchi M, Yano S, Ban T. Impact of reduced potassium nitrate concentrations in nutrient solu-

tion on the growth, yield and fruit quality of melon in hydroponics. Scientia Horticulturae 2013;164: 221-231.

[160] Brandt K, Molgaard JP. Organic agriculture: Does it enhance or reduce the nutritional value of plant foods? Journal of Science of the Food and Agriculture 2001;81: 924-931.

[161] Chessy AW, Bui L, Renaud ENC, van Horn M, Mitchell AE. Three years comparison of the content of antioxidant microconstituents and several quality characteristics in organic and conventionally managed tomato and bell peppers. Journal Agriculture and Food Chemistry 2006;54: 8244-8252.

[162] Heeb A, Lundegardh B, Ericsson T, Savage GP. Nitrogen affects yield and taste of tomatoes. Journal of the Science of Food and Agriculture 2005;85: 1405-1414.

[163] Caris-Veyrat C, Amiot MJ, Tyssandier V, Grasselly D, Buret M, Mikolajczak M, et al. Influence of organic versus conventional agriculture practice on the antioxidant microconstituents content of tomatoes and derived purees; consequences on antioxidant plasma status in humans. Journal of Agriculture and Food Chemistry 2004;52: 6503-6509.

[164] Pieper JR, Barrett DM. Effect of organic and conventional production systems on quality and nutritional parameters of processing tomatoes. Journal of the Science of Food and Agriculture 2009;89: 177-194.

[165] Hallmann E. The estimation of crop and quality fruits of selected types of tomato cultivated on mineral rockwool. PhD thesis, Department of Horticulture, WULS-SGGW; 2003.

[166] Riahi A, Hdiner CH, Sanaa M, Tarchoun N, Kheder MB, Guezal N. Effect of conventional and organic production system on the yield and quality of field tomato cultivars grown in Tunisia. Journal of the Science of Food and Agriculture 2009;89: 2275-2282.

[167] Worthington V. Nutritional quality of organic versus conventional fruits, vegetables, and grains. Journal of Alternative and Complementary Medicine 2001;7: 11-173.

[168] Hallmann E. The influence of organic and conventional cultivation systems on the nutritional value and content of bioactive compounds in selected tomato types. Journal of Science of the Food and Agriculture 2012;92: 2840-2848.

[169] Auerswald H, Schwarz D, Kornelson C, Krumbein A, Bruckner B. Sensory analysis, sugar and acid content of tomato at different EC values of the nutrient solution. Scientia Horticulturae 1999;82(3-4): 227-242.

[170] Lacatus V, Botez C, Chelu M, Mirghis R, Voican V. The influence of organic and mineral fertilizers on tomato quality for processing. Acta Horticulturae 1994;276: 329-332.

[171] Naidu KA. Vitamin C in human health and disease is still a mystery? An overview. Nutrition Journal 2003;2: 7.

[172] Sima R, Maniutiu D, Apahidean AS, Apahidean M, Lazar V, Muresan C. The influence of fertilization on greenhouse tomatoes cultivated in peat bag system. Bulletin UASVM Horticulture 2009;66(1): 455-460.

[173] Gannella M, Serio F, Conversa P, Santamarina P. Yield and qualtiy of lettuce grown in floating system using different sowing density and pant spatial arrangements. Acta Horticulturae 2003;614: 687-692.

[174] Siomos AS, Beis G, Papadopoulou PP, Barbayiannis N. Quality and composition of lettuce (cv. "Plenty") grown in soil and soilless culture. Acta Horticulturae 2001;548: 445-449.

[175] Omran MS, Waly TM, Abd Elnaim EM, El Nashar BB. Effect of sewage irrigation on yield tree components and heavy metal accumulation in Navel orange trees. Biological Wastes 1988;23: 17-24.

[176] Yadav RK, Goyal B, Sharma RK, Dubey SK, Minhas PS. Post-irrigation impact of domestic sewage effluent on composition of soils, crops and ground water - A case study. Environment International 2002;28: 481-486.

[177] Banin AJ, Naverot YN, Yoles D. Accumulation of heavy metal in arid zone soils irrigated with treated sewage effluent and their uptake by Rhodes grass. Journal of Environmental Quality 1981;10(4): 536-540.

[178] Mapanda F, Mangwayana EN, Nyamangara J, Giller KE. The effect of long term irrigation using wastewater on heavy metal contents of soils under vegetables in Harare, Zimbabwe. Agriculture Ecosystem and Environment 2005;107: 151-165.

[179] Mocquot B, Vangronsveld J, Clijsters H, Mench M. Copper toxicity in young maize (*Zea mays* L.) plants: Effects on growth, mineral and chlorophyll contents, and enzyme activities. Plant and Soil 1996;182: 287-300.

[180] Krishnamurti GSR, Naidu R. Speciation and phytoavailability of cadmium in selected surface soil of South Australian. Australian Journal of Soil Research 2000;38: 991-1004.

[181] Cheng S. Effects of heavy metals on plants and resistance mechanisms. A state-of-the-art report with special reference to literature published in Chinese journal. Environmental Science and Pollution Research 2003;10: 256-264.

[182] Guo GL, Zhou QX, Koval PV, Belogolova GA. Speciation and distribution of Cd, Pb, Cu and Zn in contaminated Phaeozem in north-east China using single and sequential extraction procedures. Australian Journal of Soil Research 2006;44: 135-142.

[183] Mclaughlin WI, Parker RR, Clarke JM. Metals and micronutrients-Food Safety Issues. Field Crop Research 1999;60: 143-163.

[184] Chojnacki K, Chojnacki A, Gorecka H, Gorecki H. Bioavailability of heavy metals from polluted soils to plants. Science of the Total Environment 2005;337: 175-182.

[185] Emongor VE, Ramoleman, GM. Treated sewage effluents (water) potential to be used for horticultural production in Botswana. Physics and Chemistry of the Earth 2004;29: 1101-1108.

[186] Kalavrouziotis IK, Robolas PK, Koukoulakis PH, Papadopoulos AH. Effects of municipal reclaimed water on the macro-, micronutrients of soil and *Brassica oleracea* var. Italica, and *Brassica oleracea* var. gemmifera. Journal of Agricultural Water Management 2008;95(4): 419-426.

[187] Emongor VE, Macheng BJ, Kefilwe S. Effects of secondary sewage effluent on the growth, development, fruit yield, and quality of tomato (*Lycopersicum lecopersicum* (L.) Karten). International Symposium on Vegetable Production, Quality and Process Standardization in China: a Worldwide Perspective. Acta Horticulturae 2012;944: 29-40.

[188] Asano T, Pettygrove GS. Using reclaimed municipal wastewater for irrigation. California Agriculture 1987;41: 16-18.

[189] Hussain I, Raschid L, Hanjra MA, Marikar F, van der Hoek W. Wastewater use in agriculture: Review of impacts and methodological issues in valuing impacts. Working Paper 37. International Water Management Institute, Colombo, Sri Lanka, 2002.

[190] Sanderson KC. Introduction to the workshop on wastewater utilization in horticultue. HortScience 1986;21: 23-24.

[191] Bozkurt MA, Yaliga T. The effects of waste water sludge application on the yield, growth, nutrition and heavy metal accumulation in apple trees growing in dry conditions. Turkish Journal of Agriculture and Forestry 2003;27: 285-292.

[192] Kiziloglu FM, Turan M, Sahin U, Kuslu Y, Dursun A. Effects of untreated and treated wastewater irrigation on some chemical properties of cauliflower (*Brassica oleracea* L. var. botrytis) and red cabbage (*Brassica oleracea* L. var. rubra) grown on calcareous soil in Turkey. Agriculture Water Management 2008;95: 716-724.

[193] Wattanapreechanon K, Wattanapreechanon E. Development of soilless culture for crop production at Chitralada Palace. Towards the year 2000: Technology for Rural Development. Proceedings of the International Conference. Chulalongkorn University, Bangkok, Thailand, August 25-26, 1997.

[194] Paul C. Health and hydroponics. Practical Hydroponics & Greenhouse 2000;53(4): 28-30.

[195] Jiang WJ, Yu HJ. Current situation and perspective of protected horticulture in China. International Workshop: The Production in the Greenhouse after the Era of the Methyl Bromide. April 1-3, 2004, Comiso, Italy.

[196] Ratanakosl P. Soilless culture not complex as we think. Kasikorn 1997;6(6): 587-592.

[197] Hanna HY. Influence of cultivar, growing media, and cluster pruning on greenhouse tomato yield and fruit quality. HortTechnology 2009;19(2): 395-399.

[198] Hanna HY, Properly recycled perlite saves money, does not reduce greenhouse tomato yield, and can be reused for many years. HortTechnology 2005;15: 342-345.

[199] Hanna HY, A stir and distinct technique to recycle perlite for cost effective greenhouse tomato production. Journal of Vegetation Science 2006;12(1): 51-63.

[200] Hanna HY, Smith DT. Recycling perlite for more profit in greenhouse tomatoes. Louisiana Agriculture 2002;45: 9.

[201] Chretien SA, Gosselin A, Dorais M. High electrical conductivity and radiation-based water management improve fruit quality of greenhouse tomatoes grown in rockwool. HortScience 2000;35: 627-631.

[202] del Amor FM, Martinez V, Cerda A. Salt tolerance of tomato plants as affected by stage of plant development. HortScience 2001;36: 1260-1263.

[203] Schwarz D. Concentration and composition of nutrient solution affect root formation of young tomato. Acta Horticulturae 2003;609: 103-108.

[204] Papadopoulos AP. Growing greenhouse tomatoes in soil and in soilless media. Publication 1865/E. Communications Branch, Agriculture and Agri-food Canada, Canada; 1991.

[205] Straver WA. Inert growing media for greenhouse tomatoes. In: Proceedings of Greenhouse Tomato Seminar. ASHS Seminar Series, American Society for Horticultural Science Press, Alexandria, VA, USA; 1995.

[206] Benoit F Ceustermans N. Consequences of Closed soilless growing systems for the recirculating nutrient solution and the production techniques. Acta Horticulturae 2004;633: 331-340.

[207] Van Noordwijk M. Synchronization of supply and demand is necessary to increase efficiency of nutrient use in soilless horticulture. In: van Beusichem ML (ed.). Plant Nutrition-Physiology and Applications. Kluwer Academic Publishers. 1990; p. 525-531.

[208] Incroccci L, Malorgio F, Della Bartola A, Pardossi A. The influence of drip irrigation or subirrigation on tomato grown in closed loop substrate culture with saline water. Scientia Horticulturae 2006;107: 365-372.

[209] Rumia TW, van Os EA, Bollen GJ. Disinfection of drain water from soilless culture by heat treatment. Netherlands Journal of Agricultural Science 1988;36: 231-238.

[210] Voogt W. Meststofverbruik: Realizatie en Normerbruik. Applied Plant Research, Naaldwijk Internal Report, 2003;p.15.

[211] Sonneveld C. Mineralenbalansen Bij Kasteelten. Meststoffen, 1993;p.44-49.

[212] Sonneveld C. The salt tolerance of greenhouse crops. Netherlands Journal of Agricultural Science 1988;36: 63-73.

[213] Sonneveld C. van den Bos AL. Effects of nutrient levels on growth and quality of radish (*Raphanus sativus* L.) grown on different substrates. Journal of Plant Nutrition 1995;18: 501-513.

[214] Ruijs MNA. Van Grondteelt Naar Gesloten Teelt. Groenten en Fruit Vakdeel Glasgroenten, 1992;2: 64-65.

[215] Abd-Elmoniem EM, El-Behairy UA. Effect of reusing perlite and pumice as a substrate on yield and mineral composition of strawberry plants. Egyptian Journal of Horticulture 2004;31: 13-21.

[216] Rea E, Salerno A, Pierandrei F. Effect of substrate and nutrient solution reuse on ranunculus and anemone plant production in a closed soilless system. Acta Horticulturae 2008;779: 542-546.

[217] Celikel G, Caglar G. The effects of re-using different substrates on the yield and earliness of cucumber on autumn growing period. Acta Horticulturae 1999;492: 259-264.

[218] Giuffrida F, Leonardi C, Marfa O. Substrate reuse in tomato soilless cultivation. Acta Horticulturae 2007;801: 1577-1582.

[219] Acuna R, Bonachela S, Magan JJ. Response of a sweet pepper crop grown in new and two-year-old reused rockwool slabs in greenhouse on the Mediterranean coast of south-east Spain. Acta Horticulturae 2005;697: 189-194.

[220] Fernandes C, Cora JE, Braz LT. Effects of the reutilization of substrates on its physical properties on growing cherry tomato. Horticulturae Brasileira 2006;24: 94-98.

[221] Urrestarazu M, Mazuela PC, Martinez GA. Effect of substrate reutilization on yield and properties of melon and tomato crops. Journal of Plant and Nutrition 2008;31: 2031-2043.

[222] Montero JI, Anton A, Munoz P, Lorenzo P. Transpiration from geranium grown under high temperatures and low humidifies in greenhouses. Agricultural and Forest Meteorology 2009;107: 323-332.

[223] Benoit F, Cuestermans N. A decade of research on polyurethane foam (PUR) substrate. Plasticulture 1994;104: 47-53.

[224] Hardgrave M. An evaluation of polyurethane foam as a reusable substrate for hydroponic cucumber production. Acta Horticulturae 1995;401: 201-208.

[225] Wilson GCS. The effect of various treatments on the yield of tomatoes in re-used perlite. Acta Horticulturae 1988;221: 373-382.

[226] Kang TM, Jung HB. Effect of rock wool classification on the growth and yield in long term culture of tomatoes. Journal Korean Society of Horticultural Science 1995;13: 352-353.

[227] Beavre OA. Base fertilizer and re-using of peat bag for tomato. Acta Horticulturae 1980;99: 11-16.

[228] Kampf AN, Jung M. The reuse of carbonized rice hulls as a horticultural substrate. Acta Horticulturae 1991;294: 271-283.

[229] Aendekerk TGL. Decomposition of peat substrate in relation to physical properties and growth of Chamaecyparis. Acta Horticulturae 1997;450: 191-198.

[230] Aendekerk TGL. Decomposition of peat substrate in relation to physical properties and growth of Skimmia. Acta Horticulturae 2001;548: 261-268.

[231] Prasad M, O'Shea J. Relative breakdown of peat and non-peat growing media. Acta Horticulturae 1999;401: 473-486.

[232] Pardossi A, Carmassi G, Diara C, Incrocci L, Maggini R, Massa D. Fertigation and substrate management in closed soilless culture. Dipartimento di Biologia delle Piante Agrarie, University of Pisa, Italy; 2011, p.63.

[233] Djedidi M, Geraspoulos D, Maloupa E. The effect of different substrates on the quality of F. Carello tomato (*Lycopersicon esculentum* Mill.) grown under protection in a hydroponic system. Cahier Option Mediterranneans 1999;31: 379-383.

[234] Hassanpouraghdam MB, Tabatabaei SJ, Nazemiyeh L, Vojodi L, Aazami MA. Essential oil composition of hydroponically grown *Chrysanthemum balsamita* L. Journal of Essential Oil Bearing Plants 2008;11: 649-654.

[235] Hassanpouraghdam MB. Flowerheads volatile oil composition of soilless culture grown *Chrysanthemum balsamita* L. Natural Product Research 2009;23: 672-677.

[236] Mairapetyan SK. Aromatic plant culture in open air hydroponics. Acta Horticulturae 1999;503: 33-42.

[237] Manukyan AE, Heuberger HT, Schnitzler WH. Yield and quality of some herbs of the Laminaceae family under soilless greenhouse production. Journal of Applied Botany and Food Quality 2004;78: 193-199.

[238] Dorais M, Papadopoulos AP, Luo X, Leonhart S, Gosselin A, Pedneault K, Angers P, Gaudreau L. Soilless greenhouse production of medicinal plants in North Eastern Canada. Acta Horticulturae 2001;554: 297-304.

[239] Hassanpouraghdam MB, Tabatabaei SJ, Nazemiyeh H, Aflatuni A. N and K nutrition levels affect growth and essential oil content of Costmary (*Tanacetum balsamita* L.). Journal of Food Agriculture and Environment 2008;6: 150-154.

[240] Suh E, Park K, Park K. Effect of different concentrations of nutrient solutions on the growth, yield and quality of basil. Acta Horticulturae 1999;502: 56-61.

[241] Udagawa Y. Some responses of Dill (*Anethum graveolens*), grown in hydroponic, to the concentration of nutrient solution. Acta Horticulturae 1995;396: 203-210.

[242] Hassanpouraghdam MB, Tabatabaei SJ, Aazami MA, Shekari F. Soilless culture production of Alecost [*Chrysanthemum balsamita* (L) Baill.]: A Preliminary Study. Romanian Biotechnological Letters 2010;15(5): 5530-5536.

[243] Haddad M. Effect of three substrates on growth, yield and quality of tomato by the use of geothermal water in the south of Tunisia. Journal of Food Agriculture and Environment 2007;5(2): 175-178.

[244] Olympios CM. Soilless media under protected cultivation rockwool, peat, perlite and other substrates. Acta Horticulturae 1995;401: 443-451.