ISSN 1392-3196
Žemdirbystė=Agriculture, vol. 99, No. 4 (2012), p. 399–408
UDK 635:631.879.4:631.878

Vegetable quality and productivity as influenced by growing medium: a review

Margit OLLE[1], Mahieu NGOUAJIO[2], Anastasios SIOMOS[3]

[1]Jogeva Plant Breeding Institute
Aamisepa 1, Jõgeva alevik 48309, Estonia
E-mail: margit.olle@jpbi.ee

[2]Department of Horticulture, Michigan State University
A4440-D Plant and Soil Sciences Building, East Lansing, Michigan, USA

[3]Department of Horticulture, Aristotle University of Thessaloniki
54124 Thessaloniki, Greece

Abstract

The aim of the review is to present an overview of the effects of mineral soil, inorganic and organic growing media on the growth, development, yield and quality of vegetables grown under greenhouse conditions. The findings from the literature suggest that the yield of various vegetables tends to be higher for the plants grown in various growing media compared to those grown in the soil. A number of authors have reported that dry matter, sugar, soluble solids, vitamins and carotenoids content in tomatoes; acidity and taste have better marks when grown in soilless culture systems compared to soil. Only very few authors have indicated that soil culture could increase acidity, dry matter, carotenoids and sugar content in tomatoes compared to soilless culture systems. Growth and development of vegetables are enhanced, when plants are grown in inorganic media compared to organic ones. For yield enhancement several authors have recommended growing vegetables in inorganic media (rockwool, sand) rather than organic media. Furthermore, there is a growing body of studies indicating the benefit of mixing organic and inorganic components for vegetable growing media with improved performance in greenhouse production. In most cases, the addition of compost did not change the yields of vegetables grown on organic media. Also it is difficult to draw broad conclusions on the impact of various organic substrates on the chemical composition of vegetables based on the information in the literature. Some inorganic substrates can influence growing medium so that vegetables grow faster, but that may depend on substrate used. As a substrate, zeolite had advantages over perlite, as it increased growth of crisp-head lettuces. As observed with organic media, it is difficult to draw general conclusions on the impact of inorganic media on the chemical composition of vegetables. Results vary with the crop and the chemical composition and availability of elements of the inorganic substrate.

Key words: compost, growing medium, peat, perlite, rockwool, sand, vegetables, vermiculite.

Introduction

The term ‘growing medium’ is amongst others used to describe the material used in a container to grow a plant. The terms ‘substrate’ (Schroeder, Sell, 2009; Vaughn et al., 2011) and ‘rooting medium’ (Blok, Verhagen, 2009) are also used as synonyms. In the United Kingdom some people still use the term ‘compost’ in the same context. However, compost is technically the product of a composting operation (e.g., a compost heap at the bottom of the garden) and therefore could be misleading. On the other hand, composted materials have routinely been used as a growing medium or components of growing media (Schroeder, Sell, 2009; Nair et al., 2011).

Growing media are materials, other than soils *in situ*, in which plants are grown. These can include organic materials such as peat, compost, tree bark, coconut (*Cocos nucifera* L.) coir, poultry feathers, or inorganic materials such as clay, perlite, vermiculite, and mineral wool (Grunert et al., 2008; Vaughn et al., 2011) (Table 1) or mixes such as peat and perlite; coir and clay, peat and compost (Nair et al., 2011). Also, mineral soil or sand has been used for growing vegetables in greenhouses.

Growing media have three main functions: 1) provide aeration and water, 2) allow for maximum root growth and 3) physically support the plant. Growing media should have large particles with adequate pore spaces between the particles (Bilderback et al., 2005). Appropriate particle size selection or combination is critical for a light and fluffy (well-aerated) medium that promotes fast seed germination, strong root growth and adequate water drainage.

Various ingredients have been used to produce growing media for vegetable production. Throughout the world, the raw materials used vary based on their local availability (Schmilewski, 2009). Such raw materials can be inorganic or organic, but growing media are often formulated from a blend of different raw materials in order to achieve the correct balance of air and water holding capacity for the plants to be grown as well as for the long-term stability of the medium (Bilderback et al., 2005; Nair et al., 2011).

Table 1. Examples of inorganic and organic media used in greenhouse production of vegetables (Olympios, 1999)

Inorganic media		Organic media
Natural media	Synthetic media	
1. Sand	1. Foam mats	1. Sawdust
2. Gravel	(polyurethane)	2. Bark
3. Rockwool	2. "Oasis"	3. Wood chips
4. Glasswool	(plastic foam)	4. Peat
5. Perlite	3. Hydrogel	5. Fleece
6. Vermiculite		6. Marc
7. Pumice		7. Cocosoil
8. Expanded clay		
9. Zeolite		
10. Volcanic tuff		
11. Sepiolite		

Worldwide, a high percentage of the hydroponic industry uses inorganic growing media such as rockwool, sand, perlite, vermiculite, pumice, clays, expanded polystyrene, urea formaldehydes and others (Sawan et al., 1999; Böhme et al., 2001; San Bautista et al., 2005; Böhme et al., 2008), while only about 12% uses organic growing media (Donnan, 1998) such as peat, bark, wood residues (leaf mould, sawdust, barks), coir, bagasse, rice hulls and others. The most popular growing media for greenhouse production of vegetables is rockwool (Islam, 2008). Rockwool is the preferred material because: 1) it is essentially almost chemically and biologically inert, making it free of any potential pests, diseases, and weed seeds; 2) rockwool slabs and blocks can be irrigated frequently as they drain freely and can thus be managed to provide an optimum ratio between air and water for crop production throughout the growing season (Bussell, Mckennie, 2004).

The vast amount of solid waste (substrate and plant material) produced each year is one of the biggest problems associated with greenhouse horticulture in some European countries. The non-biodegradability of these mainly inorganic substrates (e.g., clay, perlite and mineral wool) causes environmental concern and has prompted the search for alternative growing media (Grunert et al., 2008; Vaughn et al., 2011). However, there is no growing medium that can be labelled as the "best" since each particular medium has both advantages and disadvantages. Several factors determine the type of growing medium appropriate for specific growing conditions. Although crop performance (yield and quality) is usually the primary factor in developing a growing medium, other traits such as cost, re-use or recycling potentials are critical for a sustainable production system.

Various materials are used for substrate preparation such as peat, pine bark, sawdust, coco-fiber and cacao shell (Nurzynski, 2006; Grunert et al., 2008). The physical and chemical characteristics of the medium, together with the growing techniques (e.g., fertigation) employed, will determine the yield and quality of the vegetables that are produced (Grunert et al., 2008).

Most vegetables are established from transplants grown in trays using growing media. Therefore, many studies have focused on vegetable seed germination and transplant establishment in various growing media (Nair et al., 2011). However, the effects of growing medium on vegetable production (especially post transplant) are not well known. The importance of growing medium choice, relative to other production factors, needs to be evaluated for hydroponic vegetable production. Several studies have investigated the effect of growing media on the yield of vegetables. However, only a few studies investigated the effects of the growing medium on the quality parameters of the crop. An early review by Gruda (2009) strongly suggests changes in the quality parameter of many vegetables in response to the growing medium used. While the study focused more on the comparison of growing medium with soil it is likely that a broad range of responses would be observed among growing media of different composition and structure. Therefore, the aim of the present review was to provide a comprehensive overview of the effects of mineral soil, inorganic and organic growing media on the growth, development and yield as well as on quality (chemical composition and the incidence of some physiological disorders) of vegetables grown under greenhouse conditions.

Mineral soil versus growing medium

Most greenhouse vegetable production systems use either hydroponic systems with rock wool or perlite or various organic soilless substrates. Soilless growing media are easier to handle and may provide a better growing environment compared to soil (Bilderback et al., 2005; Mastouri et al., 2005). In a study comparing various growth media, Bilderback et al. (2005) showed that the head weight of lettuce was highest in plants grown in tea waste compost, lower in plants grown in tree bark compost and lowest in plants grown in soil (Mastouri et al., 2005). Moreover, crops reached maturity earlier when the plants were grown in tea waste compost or in tree bark compost compared to the soil. In cucumber, the total yield was higher for plants grown in nutrient film technique (NFT) compared to sandy soil (Al-Harbi et al., 1996).

According to Gruda (2009), a number of authors have reported improved uniformity in weight, size and texture of tomatoes grown in soilless culture systems compared to those grown on soil. A few authors reported that soil culture could increase the size of tomatoes compared to soilless culture systems (Gruda, 2009). Alan et al. (1994) grew tomato plants in soil, perlite, peat, sand, pumice and different combinations of them. Their results showed that the highest total as well as marketable yield was produced with a mixture of 80% pumice + 10% perlite + 10% peat medium, providing about 30% more product in comparison to the soil. In other experiments with tomatoes the following media were used: perlite, 1:1 perlite-sand, 1:1 peat-sand, sand, lava rock, 3:1 sawdust-perlite, 3:1 wood-shavings-perlite, decomposed pine bark, 1:1 ground pine (*Pinus brutia*) bark-perlite and 1:1 ground pine (*Pinus nigra*) bark-perlite (Gül, Sevican, 1992) or peat + volcanic tuff + spent mushroom compost

(1:1:1), volcanic tuff + spent mushroom compost (1:1), peat + volcanic tuff (1:1) and volcanic tuff (Celikel, 1999) and were compared with the soil. It was found that early and total yield was higher in plants grown in various growing media than those in the soil. In contrast to the above findings, Fandi et al. (2008) found rather higher total yield and yield per plant in tomato grown in soil or tuff compared to sand.

In addition to yield, the growing medium has shown effects on other plant parameters. Dry matter content was highest in lettuce grown in tea waste compost and lower in tree bark compost (Mastouri et al., 2005). Lettuce plants harvested from perlite or pumice culture had a lower dry matter, chlorophyll, Mg, Fe and Mn content and a higher titratable acidity as well as total N, P, and K content, in comparison with the plants harvested from the soil culture (Siomos et al., 2001). Moreover, lettuce plants of the soil culture were free from tipburn symptoms, while plants in soilless culture especially perlite developed significant tipburn.

When tomato plants were grown in soil, perlite, peat, sand, pumice either alone or in combination, the highest ascorbic acid was obtained from perlite; the highest total soluble solids concentration from peat and (the lowest from the mixture of 50% pumice + 50% sand); the highest acidity from sand and the lowest acidity from the mixture of 50% pumice + 50% sand (Alan et al., 1994). Celikel (1999) compared the following substrates: peat + volcanic tuff + spent mushroom compost (1:1:1), volcanic tuff + spent mushroom compost (1:1), peat + volcanic tuff (1:1), volcanic tuff and soil. The ascorbic acid content of the fruit did not differ significantly among growing media and soil. Angelis et al. (2001) reported similar findings with no significant effect of growing medium (perlite and rockwool) and soil on tomato total soluble solids and titratable acidity. However, Fandi et al. (2008) reported higher total soluble solid in tomato fruit produced from tuff or sand growing medium in two seasons compared to fruit growing in soil. Citric acid content was not affected by growing medium in the first season but was higher from tuff or sand growing medium than from soil in the second season. For most sensory characteristics assessed, the type of growth medium (soil or rockwool) had no or little effect. However, for the characteristics related to texture (crispness and firmness), soil-grown tomatoes were slightly but significantly softer than the rockwool-grown ones (Thybo et al., 2005).

Gruda (2009) presented a review comparing soil and soilless culture with regard to the quality properties of tomato fruit. From his overview it can be concluded that most authors reported to have no differences in quality properties of tomato fruits produced in soil or in soilless culture systems. A number of authors have reported that dry matter, sugar, soluble solids, vitamins and carotenoids content in tomatoes; acidity and taste have better marks when grown in soilless culture systems compared to soil (Gruda, 2009). Only very few authors reported that soil culture could increase dry matter, carotenoids, sugar content and acidity in tomatoes compared to soilless culture systems (Gruda, 2009).

Conclusions

Therefore, the findings from the literature suggest as follows:

1. The yield of various vegetables tends to be higher for the plants grown in various growing media than those grown in the soil, indicating that the growing media could meet plant demands better than the soil.

2. Substrates can be mixed according to plant needs.

3. In addition, NFT-grown plants yielded better than soil-grown plants because nutrient solution in rockwool could be added several times per day but in soil it was added fewer times, therefore the yield in soil-grown plants could be lower than in rockwool-grown plants.

4. In contrast to the above literature outlining the benefits of various growing media, Fandi et al. (2008) found high yield in plants grown in soil compared to sand substrates.

5. Based on methodology and data of Fandi et al. (2008), we presume that this may be due to the actual status of water and oxygen in the media, since oxygen deficiency restricts root respiration.

6. Lack of oxygen in the root-zone negatively affects water and nutrient uptake, which eventually reduced fruit weight in the soilless culture.

7. Unlike yield and other growth parameters, it is relatively difficult to draw robust conclusions on the impact of growing medium on the chemical composition of vegetables. Most studies report no difference between soil and soilless culture systems. However, when differences exist, they tend to be in favour of vegetables grown in soilless systems.

Organic versus inorganic growing medium

Organic components decompose during crop production and may change both the physical and chemical composition of the medium (Bilderback et al., 2005). This may in turn affect crop growth and development. Compared with inorganic media (rockwool and sand), organic media (peat moss and baggasse) have been shown to inhibit the vegetative growth and fruit yield of tomato with more pronounced effects when urea was the sole N source (Ikeda et al., 2001). However, the growth inhibition was mitigated by the combined application of nitrate with urea and when nitrate was the sole N source. Higher yield (total, marketable and early) and lower weight per fruit of seven tomato cultivars were also obtained when grown on rockwool than on coir straw – Cocovita (Kobryń, 2002). Growing media based on peat and peat with cocos derivatives were tested against mineral wool for tomato. Results showed that plants grown in the pure peat rooted more easily than those grown in the peat-coco or mineral wool but the total yield was similar for all media (Grunert et al., 2008) (Table 2). Similar yield of tomato plants grown in straw and rockwool has also been reported by Nurzynski (2006). Tomato plants grown in perlite produced higher total marketable yield than plants grown in either of the other media (pine bark and rockwool) (Hanna, 2009).

Cucumber plant development was quicker and the yield was higher, when plants were grown in perlite or rockwool compared to coconut fibre (Böhme et al., 2001). Common purslane (*Common purslane*) was taller and fresh weights of leaves and stems were higher, when plants were grown in peat compared to vermiculite, coir or perlite-grown plants (Cros et al.,

Table 2. Summary of the results of comparative substrate tests carried out using the grape tomato 'Tricia' in 2006

Fertigation regime	Substrate	Yield kg m^{-2}	Number of fruits m^{-2}	Number of fruits with blossom-end rot (BER) m^{-2}	Taste
Wet	mineral wool	47.95 a	335.3 a	7.1 a	4.68 a
	peat	49.25 a	336.5 a	5.8 a	4.64 a
	peat-cocos	51.08 a	349.8 a	5.9 a	5.04 a
Dry	mineral wool	51.77 a	357.0 a	5.0 b	ND
	peat	51.61 a	362.9 a	2.1 ab	ND
	peat-cocos	51.47 a	353.4 a	1.3 a	ND

Notes. Fruit taste was evaluated on a scale of 0 (= absolutely not tasty) to 10 (= very tasty). Asterisks indicate data that are averages of different treatments. Values with different letters appended are statistically different from one another ($P < 0.05$) as indicated by *ANOVA* analysis (SPSS 11.5); ND = not determined (Grunert et al., 2008).

2007) (Table 3). Development and yield of cucumber grown on sheepwool slabs, peat slabs, coconut fibre slabs, perlite and rockwool slabs were investigated and the structure of all media analyzed before and after use (Böhme et al., 2008). The air capacity of sheepwool before use was much higher (70%) than that of the other media (18–58%) but decreased with use to 43%. The water capacity of sheepwool was about 23% before use and increased up to 44% after use. The highest yield was recorded on sheepwool. There was no significant difference in cucumber production in plants grown in recyclable plant growth substrate or in rockwool (Huber et al., 2005). Three media types, coarse-grade perlite, medium-grade perlite, and pine bark were compared for efficiency of growing cucumbers (production and potential costs). Fruit yield was the same among media treatments (average of 6 kg (13.2 lb) per plant) (Shaw et al., 2004). In another study, almond shell residue was non-limiting in comparison to rockwool for melon and tomato crops in relation to fertigation parameters, water uptake and yield (Urrestarazu et al., 2005).

Table 3. Vegetative parameters of plants of common purslane grown in different substrates in September 2004 (expt. 3) (Cros et al., 2007)

Substrates	Vegetative parameters		
	plant height cm	leaf fresh weight g m^{-2}	stem fresh weight g m^{-2}
Peat	14.7 a	1.275.7 a	964.9 a
Peat-perlite (3:1)	14.2 a	1.262.6 a	869.8 ab
Peat-perlite (1:1)	13.6 a	1.134.9 b	787.8 b
Vermiculite	9.3 b	625.2 c	317.5 c
Coir	6.3 c	369.1 d	164.9 d
Perlite	6.2 c	432.5 d	168.1 d

Note. Within column means followed by different letters are significantly different by Tukey's multiple range test ($P = 0.05$).

On the other hand, the interest in the use of mixtures of inorganic and organic materials as growing media in soilless culture is increasing in parts of the world where the mixtures have not been used in common practice. Addition of inorganic substances to organic ones has resulted in a better plant growth and higher yield probably owing to increasing water-holding capacity and aeration of peat. Better aeration of peat promotes vigorous root growth, which allows better growth of foliage and therefore increases whole yield of plants. This demonstrates that inorganic substances including vermiculite, perlite and coal ash could partially replace peat (Vaughn et al., 2011).

Sixteen media prepared from peat, coir, vermiculite, or perlite were used to determine the optimum growing media for tomato transplants. Transplants grown with >50% coir exhibited reduced plant growth compared to peat-grown transplants, a response that may be associated with high N immobilization by microorganisms and high C:N ratio (Arenas et al., 2002). Forterra Royal GRO 1 (coconut coir/vermicompost) and Forterra Royal GRO 2 (aged pine bark/coconut coir/vermicompost) attained significantly higher marketable yields per tomato plant compared with the plants grown in rockwool (Surrage et al., 2010). Cucumber plants were grown in twenty five combinations of peat moss, vermiculite, composted sawdust and crop residues compost (Sawan et al., 1999); the highest plant growth and subsequently the highest yield were obtained by reducing peat moss volume from 50% to 20% in the mixture. The highest cucumber yield was obtained with a 1:1 mixture of peat and vermiculite. Plants grown in 3:1 peat-vermiculite, 3:1 peat-perlite, 3:1 peat-coal ash outyielded those grown in peat alone (Gao et al., 2010). For cucumber, greater marketable yield and a lesser incidence of abnormal fruits were observed on the perlite with rice hull or with carbonized rice hull as compared to the pure perlite (Lee et al., 1999 a). Yield of cucumber grown in bags with composted pig manure alone or mixed with perlite (50:50) was higher when bag height was 10 cm than 20 cm (Naddaf et al., 2011).

Results indicate that addition of shredded maize stems in perlite and pumice could improve their properties over inorganic media alone and could lead to improved plant development and yield for greenhouse tomato (Tzortzakis, Economakis, 2005; 2008). Higher total yield of tomato was obtained from plants grown in perlite + peat and perlite than from pumice, volcanic ash, pumice + peat and volcanic ash + peat (Tüzel et al., 2001). The perlite-based mixtures resulted in higher leaf area and stem diameter of tomato plants, while cultivation in coco peat alone delayed harvest (Traka-Mavrona et al., 2001). Growing medium of 2 peat:1 vermiculite:1 compost (by volume) was amended with 0, 0.6, 1.2, 1.8, or 2.4 % weight by weight of alfalfa-based organic amendment and incubated for 0, 1, 2, 3, or 4 weeks. Relative to growth in medium with no amendments, plants growing in the amended medium had increased stem diameter, height, leaf chlorophyll content, and plant dry weight (90% to 160% more), provided the amended medium was incubated for at least one week (Nair et al., 2011).

Some other findings indicated however that there are no beneficial effects of mixing organic and inorganic substances for growing medium. Although cucumber seedlings grown in peat were taller and had larger leaf area than the seedlings grown in peat-perlite or peat-zeolite mixtures, they accumulated less dry matter (Jankauskienė, Brazaitytė, 2008). When zeolite is mixed into peat substrates, seedling photosynthesis productivity becomes greater than that of plants grown on peat. Nevertheless, the mixing of zeolite and perlite into seedling growing medium did not improve cucumber yield (Jankauskienė, Brazaitytė, 2008). Formulated perlite (fine and coarse granule), peat moss, rice hull and carbonized rice hull were evaluated for impacts on tomato total yield and average fruit weight. The best performances were obtained with pure perlite, followed by perlite mixed with rice hull and carbonized rice hull, in that order. Fruit yield decreased with increasing concentration of rice hull in the growing medium (Lee et al., 1999 b).

The effect of growing medium on the quality of tomatoes and cucumbers was investigated by determining texture, colour and taste by sensory evaluation and by chemical analysis (Luoto, 1984). Results indicated that the growing medium affected the dry matter content, pH and acidity as well as quality of tomato as judged. Tomatoes grown in peat were considered redder, softer and tastier and the taste differences were greatest at the beginning of the harvesting season. Rice hull alone resulted in increased sugar content of tomato fruit when compared with perlite (fine and coarse granule) (Lee et al., 1999 b). Growing medium had no distinct effect on the content of sugars and ascorbic acid, but tomatoes grown on Cocovita contained fewer mineral elements. Fruits from plants grown on Cocovita contained more dry matter than those grown on rockwool (Kobryń, 2002). The content of dry weight, ascorbic acid and sugars in fruit differed to a small extent between tomato plants grown on straw or rockwool (Nurzynski, 2006). Formulated perlite (fine and coarse granule), peatmoss, rice hull and carbonized rice hull were tested in tomato. Rice hull alone resulted in increased sugar contents of the fruits to over 6.0° Brix (Lee et al., 1999 b). Cros et al. (2007) carried out three experiments using peat, vermiculite, coir, perlite, and mixtures of peat and perlite (3:1 and 1:1 v/v) cultivating common purslane (*Common purslane*). Plants grown in peat substrate had the highest total fatty acid content, alpha-linolenic acid, and linoleic acid, whereas the highest proportion of alpha-linolenic acid to total fatty acids was obtained in plants when grown in either coir or perlite.

Chemical parameters of cucumber were also affected by the growing media, while medium had no effect on texture. The colour of cucumber at the end of the harvest season was affected by growing media (Luoto, 1984). Cucumber grown in mineral wool had the best taste (based on sensory evaluation, which was carried out immediately after harvesting) at the beginning of the harvesting season.

Addition of shredded maize stems in perlite and pumice could improve their properties over inorganic media alone and did not affect occurrence of blossom-end rot (BER) on tomato fruit (Tzortzakis, Economakis, 2005; 2008). On the other hand, coco peat, alone or in mixture with perlite, contributed to an increased incidence of fruit with BER, especially under slow release fertilizer fertigation (Traka-Mavrona et al., 2001). Tomato plants grown in the pure peat or peat with cocos derivatives developed less BER than in mineral wool (Grunert et al., 2008) (Table 2). A similar trend was seen for the incidence of BER with GRO 1 (coconut coir/vermicompost) and GRO 2 (aged pine bark/coconut coir/vermicompost) having reduced BER incidence per plant when compared with rockwool (Surrage et al., 2010). Growing media based on peat and peat with cocos derivatives were tested against mineral wool. Results showed that tomato plants grown in the pure peat developed less BER in both peat substrates than in mineral wool. No differences between substrates could be observed in the quality of the fruit produced. On the other hand, flavour tests demonstrated that plants grown on peat substrate produced more tasty fruits under certain conditions (Grunert et al., 2008).

Disease (*Fusarium oxysporum* f. sp. *Radicis lycopersici*) incidence decreased from an average ranging from 35.9% to 75.2% in new perlite-peat mix to 0.4–26.4% in recycled perlite-peat mix (Clematis et al., 2009). Moreover, higher cucumber fruit quality was obtained by the mixture of peat to vermiculite 1:1 than in 3:1 peat/vermiculite, 3:1 peat/perlite, 3:1 peat/coal ash or peat (Gao et al., 2010).

Different physiological disorders in broccoli include brown bud, bud deformation, bracting and hollow stem, which adversely affect the quality of the product. They are related to cultivar sensitiveness but also to nutritional disorders and/or to different stressing factors. Two growing media (perlite and coconut coir dust) were tested in plants grown in containers (San Bautista et al., 2005). The type of substrate did not affect yield, but when plants were grown in perlite, broccoli buds were more affected by the brown bud disorder (San Bautista et al., 2005).

Conclusions

The findings suggested as follows:

1. Growth and development of vegetables are enhanced, when plants are grown in inorganic media compared to organic ones (Böhme et al., 2001; Ikeda et al., 2001).

2. In contrast, Tzortzakis and Economakis (2008) found that plants grew faster in organic media compared to inorganic media.

3. For yield enhancement several authors have recommended to grow vegetables in inorganic media (rockwool, sand) rather than organic media (Lee et al., 1999 b; Böhme et al., 2001; 2008; Ikeda et al., 2001; Kobryń, 2002).

4. Furthermore, there is a growing body of studies indicating the benefit of mixing organic and inorganic components for vegetable growing media with improved performance in greenhouse production (Tzortzakis, Economakis, 2005; Gao et al., 2010).

5. Addition of inorganic substances to organic substances produces higher yield probably owing to increasing water-holding capacity and aeration by organic substances, which demonstrates that inorganic substances could partially replace organic substances (Gao et al., 2010).

6. Better aeration of peat promotes vigorous root growth, which allows rapid growth of foliage and therefore increases whole plant yield.

7. Some studies have shown that vegetables grown in organic media could be tastier than those grown in inorganic media (Luoto, 1984; Grunert et al., 2008).

8. Organic media may allow plants to access critical nutrients, which in turn could allow plants to be tastier than those grown in mineral wool.

9. In some cases the type of substrate does not affect chemical composition of plants (Kobryń, 2002).

10. Flavour tests demonstrated that plants grown on peat substrate produced more tasty fruits compared to mineral wool and peat with cocos derivatives (Grunert et al., 2008).

11. The incidence of physiological disorders such as tomato blossom-end rot (BER) is likely to be greater when plants are grown in inorganic media compared to plants grown in organic media or mixtures of organic and inorganic media.

12. In inorganic media, nutrient provisioning to the crop is limited to the amounts added to the nutrient solution or irrigation. In the organic media; however, additional nutrients are released from the decomposing organic component. Therefore, plant growth and resistance to biotic and abiotic stresses could be enhanced with the use of organic components in growing media.

Organic growing medium

As indicated above, organic materials include substrates like sawdust, bark, wood chips, peat, fleece, marc, cocosoil. While all organic substrates can decompose over time, the rate of decomposition and the physical conditions of the medium vary with the parent material. That in turn may affect crop growth and development. For cucumber seedling production, sawdust was proposed as a substitute for high concentrations of peat moss media (Sawan et al., 1999). No significant difference was observed for growth of tomato transplants cultivated in wood fiber substrates or white peat (Gruda, Schnitzler, 2004). Also, vermicompost could be a substitute for peat in potting media with similar or beneficial effects on seedling performance (emergence and elongation). Most studies have reported beneficial effects of vermicompost on germination, plant growth and yield with substitutions of 20–40% of vermicompost into a commercial growth medium. These findings indicate that vermicompost enhances development of vegetables in organic growing medium. Composts are widely used and contain important amounts of nutrients depending on the source and type of compost. Most composts also provide a "warm" growing medium, which promotes root growth. Quicker root growth may help increase subsequent canopy development and overall crop performance. However, crop-specific responses should be considered when using compost and other organic substrates in vegetable production. In tomatoes, variety-specific responses should be considered when developing recommendations on the optimum proportion of vermicompost amendment to horticultural potting substrate (Zaller, 2007). Although vermicompost may provide a viable alternative to peat-based growth media, overall, Roberts et al. (2007) found little added benefit from using vermicompost. This lack of benefit could be due to the type of crop or cultivar used.

The mixture of 80% commercial peat-lite and 20% of yard trimmings/biosolids compost (1:1) was horticulturally acceptable as an alternative to 100% commercial peat-lite for cauliflower transplant production (Kahn et al., 2005).

Polat et al. (2009) studied the effects of spent mushroom compost (SMC), which is a waste product of mushroom processing on greenhouse cucumber growth as an organic matter source for substrate. The highest total fruit yield in May was obtained at 40 t ha^{-1} followed by 20 t ha^{-1}, and 80 t ha^{-1} SMC, respectively, with no difference between 80 t ha^{-1} and the control (Table 4). Medina et al. (2009) conducted a study testing the response of three vegetable species with different salt sensitivities to various organic growing media. Tomato (*Lycopersicon esculentum* var. 'Muchamiel'), courgette (*Cucurbita pepo* L. var. 'Afrodite F1') and pepper (*Capsicum annum* L. var. 'Lamuyo F1') were the least, the moderate and the most salt-sensitive species, respectively. The three crops were grown in 12 different media containing spent mushroom substrate (SMS) of either *Agaricus bisporus* (SMS-AB) or *Pleurotus ostreatus* (SMS-PO) or a 50:50 (v/v) combination of both (SMS-50). The proportions of each residue in the mixtures with peat were 25, 50, 75 and 100 % (v/v). A substrate of 100% peat was also used as control. Tomato growth was not affected by substrate type indicating that any of the media could be used for tomato production. In contrast, the other crops showed substrate specific responses. SMS-AB-based substrates and the media containing low dose of SMS-PO and SMS-50 were more appropriate for courgette and pepper (Medina et al., 2009).

Table 4. Effects of spent mushroom compost on monthly yield in May (Polat et al., 2009)

Treatments	Total yield kg m^{-2}
Control	6.120 c
20 t ha^{-1}	6.610 b
40 t ha^{-1}	7.163 a
80 t ha^{-1}	6.140 c
$LSD_{5\%}$	0.3628

Shoot dry weight of plants grown in soil supplemented with 5% and 10% of *Agaricus subrufescens* SMS were greater than that of plants grown with chemical fertilization (NPK) suggesting other benefits of specific organic substrates beyond basic nutrients provisioning (Ribas et al., 2009). Rice hull alone resulted in increased sugar content of tomato fruit when compared with peatmoss (Lee et al., 1999 b). Vermicompost improved the marketability of fruits due to lower incidence of physiological disorders (blossom-end rot and fruit cracking), while ascorbic acid content of the fruit was unaffected by the presence of vermicompost (Roberts et al., 2007).

Nitrogen content of plants increases with the amounts of the compost applied when plants are grown in organic media. Nitrate accumulation in products is a function of increasing supply of nitrate by fertilization and mineralization of soil organic matter on the one hand, and reduced availability of assimilates on the other hand (Nazaryuk et al., 2002). Therefore, the higher the nitrogen availability and the lower the assimilation intensity the greater the nitrate accumulation would be. Moreover poorly controlled flux of the soil nitrogen resulting from active mineralization of organic matter may lead to excessive accumulation of nitrate in plants (Nazaryuk et al., 2002).

Conclusions

1. In most cases (Roberts et al., 2007; Zaller, 2007) the addition of compost did not change yields of vegetables grown on organic media.

2. Also, it is difficult to draw broad conclusions on the impact of various organic substrates on the chemical composition of vegetables based on the information in the literature.

Inorganic growing medium

Results showed that cucumber seedlings grown on a urethane based recyclable plant growth medium were significantly shorter and one leaf stage behind the rockwool-grown seedlings during early stages of plant development and this delayed flowering and first fruit harvest (Huber et al., 2005). Over a 27-day harvest period there was no significant difference in cucumber fruit length and circumference for plants grown on two substrates (a urethane based recyclable plant growth substrate and rockwool) (Huber et al., 2005).

Studies conducted by Gül et al. (2005) showed zeolite, as a substrate, to have advantages over perlite, as it increased growth of crisp-head lettuces. This effect may be attributed to an increase in the uptake of some nutrients since zeolite has high cation exchange properties, and acts as a reservoir, holding elements in its structure for slow release to the rhizosphere (Gül et al., 2005).

Growth of cucumber was better and the marketable yield was higher by 30% in perlite than in expanded clay pellets (Kacjan Maršić, Jakše, 2010). Higher yield was found for cucumber grown on Polish rockwool Flormin than on Danish rockwool Grodan, but also a significant interaction of growing medium and cultivar was observed (Pirog, 1996). The fruit yield from plants on rayon polyester material (RPM) was increased significantly, compared to plants grown on minirock wool blocks due to increases in fruit size and fruit number (Logendra et al., 2001).

Rockwool retains nutrient solution and holds air, which allows plants to get nutrients more easily. Nutrient solution in rockwool can be added several times per day but in peat it is added fewer times, therefore the yield in organic medium can be lower than in inorganic media if nutrient management is not optimum. Grodan rockwool, when allowed to drain by gravitational pull contains 80% solution, 15% air pore space and 5% rockwool fibers at field capacity. This ratio of solution to air promotes vigorous root growth, which enhances foliage growth and ultimately improves whole plant yield.

Differences in cherry tomato fruit yield were observed among six inorganic substrates (sand (S), perlite (P), zeolite (Z) and mixtures (on volume basis) of P:S 2:1, Z:P 1:1, Z:S 1:1 and Z:P:S 1:1:1), with the highest performance obtained with zeolite alone (Al-Ajmi et al., 2009). The best substrate for cultivation of cherry tomato was zeolite which is probably related to its high water holding capacity and cation exchange capacity. Their results suggest that addition of sand to zeolite resulted in similar fruit yield to that obtained on perlite (Al-Ajmi et al., 2009).

Tomato plants grown in sand substrate were taller, had thicker stems, and higher fresh weight compared to plants grown on perlite and stone pumice (Haddad, 2007) (Table 5). Cherry tomato fruit quality varied among the six substrates compared by Al-Ajmi et al. (2009). Analysis of fruits indicated that K, Cu, Zn, and Fe concentrations and fiber contents were higher in Z medium followed by Z:S 1:1 medium, while protein contents and the concentrations of P, N and Mn were not affected by substrates (Al-Ajmi et al., 2009). The results suggest that addition of sand to zeolite resulted in similar fruit quality to perlite.

Table 5. Influence of three substrates on tomato growth (Haddad, 2007)

	Sand	Perlite	Stone pumice
Plant height m	2.34 a	2.09 b	2.01 b
Root fresh weight g	68.25 a	41.375 b	48.214 b
Stem diameter mm	28.51 a	22.13 b	21.17 b
Top fresh weight g	34.11 a	29.17 b	28.98 b

Note. Values are averages of 50 measurements.

The incidence of blossom-end rot (BER) was higher when tomato was grown in perlite and pumice in comparison with sand (Haddad, 2007). RPM significantly reduced the incidence of BER compared to minirock wool blocks (Logendra et al., 2001).

Disease (*Fusarium oxysporum* f. sp. *Radicis lycopersici*) incidence decreased from an average ranging from 44.4% to 61.9% in new perlite to 2.5–36.3% in recycled one (Clematis et al., 2009).

Zeolite, when compared to perlite, led to higher N and K contents in crisp-head lettuce tissues (Gül et al., 2005). Lettuce plants harvested from perlite culture had a lower chlorophyll a, total chlorophyll and Fe content and a higher chlorophyll b and Mn content than plants harvested from pumice culture (Siomos et al., 2001).

Conclusions

1. Some inorganic substrates can influence growing medium so that vegetables grow faster, but that may depend on the substrate used.

2. As a substrate, zeolite had advantages over perlite, as it increased growth of crisp-head lettuces (Gül et al., 2005).

3. At the same time, growth of cucumber was better and the marketable yield was higher by 30% in perlite than in expanded clay pellets (Kacjan Maršić, Jakše, 2010).

4. As observed with organic media, it is difficult to draw general conclusions on the impact of inorganic media on the chemical composition of vegetables. Results vary with the crop and the chemical composition and availability of elements of the inorganic substrate.

Received 12 03 2012
Accepted 04 09 2012

References

Al-Ajmi A., Al-Karaki G., Othman Y. Effect of different substrates on fruit yield and quality of cherry tomato grown in a closed soilless system // Acta Horticulturae. – 2009, vol. 807, p. 491–494

Alan R., Zuladir A., Padem H. The influence of growing media on growth, yield, and quality of tomato grown under greenhouse conditions // Acta Horticulturae. – 1994, vol. 366, p. 429–436

Al-Harbi A. R., Alsadon A. A., Khalil S. O. Influence of training system and growing media on growth and yield of cucumber cultivars // Alexandria Journal of Agricultural Research. – 1996, vol. 41, p. 355–365

Angelis G., Papadantonakis N., Spano T., Petrakis C. Effect of substrate and genetic variation on fruit quality in greenhouse tomatoes: preliminary results // Acta Horticulturae. – 2001, vol. 548, p. 497–502

Arenas M., Vavrina C. S., Cornell J. A., Hanlon E. A., Hochmuth G. J. Coir as an alternative to peat in media for tomato transplant production // HortScience. – 2002, vol. 37, p. 309–312

Bilderback T. E., Warren S. L., Owen Jr. J. S., Albano J. P. Healthy substrates need physicals too! // HortTechnology. – 2005, vol. 15, p. 747–751

Blok C., Verhagen J. B. G. M. Trends in rooting media in Dutch horticulture during the period 2001–2005: the new growing media project // Acta Horticulturae. – 2009, vol. 819, p. 47–58

Böhme M., Hoang L. T., Vorwerk R. Effect of different substrates and mineral as well as organic nutrition on the growth of cucumber in closed substrate systems // Acta Horticulturae. – 2001, vol. 548, p. 165–172

Böhme M., Schevchenko J., Pinker I. Herfort S. Cucumber grown in sheepwool slabs treated with biostimulator compared to other organic and mineral substrates // Acta Horticulturae. – 2008, vol. 779, p. 299–306

Bussell W. T., Mckennie S. Rockwool in horticulture, and its importance and sustainable use in New Zealand // New Zealand Journal of Crop and Horticultural Science. – 2004, vol. 32, iss. 1, p. 29–37

Celikel G. Effect of different substrates on the yield and quality of tomato // Acta Horticulturae. – 1999, vol. 491, p. 353–356

Clematis F., Minuto A., Gullino M. L. Garibaldi A. Suppressiveness to *Fusarium oxysporum* f. sp. *Radicis lycopersici* in re-used perlite and perlite-peat substrates in soilless tomatoes // Biological Control. – 2009, vol. 48, p. 108–114

Cros V., Martınez-Sanchez J. J., Franco J. A. Good yields of common purslane with a high fatty acid content can be obtained in a peat-based floating system // HortTechnology. – 2007, vol. 17, p. 14–20

Donnan R. Hydroponics around the world // Practical Hydroponics and Greenhouses. – 1998, vol. 41, p. 18–25

Fandi M., Al-Muhtaseb J. A., Hussein M. A. Yield and fruit quality of tomato as affected by the substrate in an open soilless culture // Jordan Journal of Agricultural Sciences. – 2008, vol. 4, p. 65–72

Gao H. B., Zhang T. J., Lv G. Y., Zhang G. H., Wu X. L., Li J. R., Gong B. B. Effects of different compound substrates on growth, yield and fruit quality of cucumber // Acta Horticulturae. – 2010, vol. 856, p. 173–180

Gruda N. Do soilless culture systems have an influence on product quality of vegetables? // Journal of Applied Botany and Food Quality. – 2009, vol. 82, p. 141–147

Gruda N., Schnitzler W. H. 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. – 2004, vol. 100, p. 333–340

Grunert O., Perneel M., Vandaele S. Peat-based organic growbags as a solution to the mineral wool waste problem // Mires and Peat. – 2008, vol. 3, p. 1–5

Gül A., Sevican A. Effect of growing media on glasshouse tomato yield and quality // Acta Horticulturae. – 1992, vol. 303, p. 145–150

Gül A., Eroğul D., Ongun A. R. Comparison of the use of zeolite and perlite as substrate for crisp-head lettuce // Scientia Horticulturae. – 2005, vol. 106, p. 464–471

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, vol. 5, p. 175–178

Hanna H. Y. Influence of cultivar, growing media, and cluster pruning on greenhouse tomato yield and fruit quality // HortTechnology. – 2009, vol. 19, p. 395–399

Huber J. J., Zheng Y., Dixon M. A. Hydroponic cucumber production using urethane foam as a growth substrate // Acta Horticulturae. – 2005, vol. 697, p. 139–145

Ikeda H., Wen Tan X., Ao Y., Oda M. Effects of soilless medium on the growth and fruit yield of tomatoes supplied with urea and/or nitrate // Acta Horticulturae. – 2001, vol. 548, p. 157–164

Islam S. Evaluating performance of ecologically sound organic substrates under different temperature regimes // International Journal of Agriculture and Biology. – 2008, vol. 10, p. 297–300

Jankauskienė J., Brazaitytė A. The influence of various substratum on the quality of cucumber seedlings and photosynthesis parameters // Sodininkystė ir daržininkystė. – 2008, vol. 27, No. 2, p. 285–294

Kacjan Maršić N., Jakše M. Growth and yield of grafted cucumber (*Cucumis sativus* L.) on different soilless substrates // Journal of Food, Agriculture and Environment. – 2010, vol. 8, p. 654–658

Kahn B. A., Hyde J. K., Cole J. C., Stofella P. J., Graetz D. A. Replacement of a peat-lite medium with compost for cauliflower transplant production // Compost Science and Utilization. – 2005, vol. 13, p. 175–179

Kobryń J. The effect of substrate type on the yield and quality of tomato fruits (*Lycopersicon esculentum* Mill.) in glasshouse cultivation // Folia Horticulturae. – 2002, vol. 14, p. 53–59

Lee B. S., Cho J.-Y., Park S. K., Ahn J.-S., Chung S.-J. Effects of substrates on the growth and fruit quality of hydroponically grown tomatoes (*Lycopersicon esculentum* Mill.) cv. Katinka // Acta Horticulturae. – 1999 (b), vol. 483, p. 147–153

Lee B. S., Lee J. H., Park S. G., Chung S. J., Seo B. S. Effects of container and substrate on plant growth and fruit quality of the hydroponically grown cucumber (*Cucumis sativus* L. cv. Chosaengnakhap) plants // Acta Horticulturae. – 1999 (a), vol. 483, p. 155–160

Logendra L. S., Gianfagna T. J., Janes H. W. Using mini-rockwool blocks as growing media for limited-cluster tomato production // HortTechnology. – 2001, vol. 11, p. 175–179

Luoto L. Effects of growing media on the postharvest quality of tomatoes and cucumbers // Acta Horticulturae. – 1984, vol. 163, p. 237–244

Mastouri F., Hassandokht M. R., Padasht Dehkaei M. N. The effect of application of agricultural waste compost on growing media and greenhouse lettuce yield // Acta Horticulturae. – 2005, vol. 697, p. 153–158

Medina E., Paredes C., Pérez-Murcia M. D., Bustamante M. A., Moral R. Spent mushroom substrates as component of growing media for germination and growth of horticultural plants // Bioresource Technology. – 2009, vol. 100, p. 4227–4232

Naddaf O. A., Livieratos I., Stamatakis A., Tsirogiannis I., Gizas G., Savvas D. Hydraulic characteristics of composted pig manure, perlite, and mixtures of them, and their impact on cucumber grown on bags // Scientia Horticulturae. – 2011, vol. 129, p. 135–141

Nair A., Ngouajio M., Biernbaum J. Alfalfa-based organic amendment in peat-compost growing medium for organic tomato transplant production // HortScience. – 2011, vol. 46, p. 253–259

Nazaryuk V. M., Klenova M. I., Kalimullina F. R. Ecoagrochemical approaches to the problem of nitrate pollution in agroecosystems // Russian Journal of Ecology. – 2002, vol. 33, p. 392–397

Nurzynski J. The yielding of greenhouse tomato grown in straw and rockwool substrates // Folia Horticulturae. – 2006, vol. 18, No. 2, p. 17–23

Olympios C. M. Overview of soilless culture: advantages, constraints and perspectives for its use in Mediterranean countries // Options Mediterraneennes. – 1999, vol. 31, p. 307–324

Pirog J. Usefulness of four growing media in greenhouse cucumber cultivation // Zeszyty problemowe postepow nauk rolniczych. – 1996, vol. 429, p. 255–258

Polat E., Uzun H. B., Topçuoglu B., Önal K., Onus A. N., Karaca M. Effects of spent mushroom compost on quality and productivity of cucumber (*Cucumis sativus* L.) grown in greenhouses // African Journal of Biotechnology. – 2009, vol. 8, p. 176–180

Ribas L. C. C., Mendonça M. M., Camelini C. M., Soares C. H. L. Use of spent mushroom substrates from *Agaricus subrufescens* (syn. *A. blazei*, *A. brasiliensis*) and *Lentinula edodes* productions in the enrichment of soil-based potting media for lettuce (*Lactuca sativa*) cultivation: growth promotion and soil bioremediation // Bioresource Technology. – 2009, vol. 100, p. 4750–4757

Roberts P., Jones D. L., Edwards-Jones G. Yield and vitamin C content of tomatoes grown in vermicomposted wastes // Journal of the Science of Food and Agriculture. – 2007, vol. 87, p. 1957–1963

San Bautista A., Rueda R., Pascual B., Maroto J. V., Lopez-Galarza S. Influence of different substrates and nutrient solutions on the yields and the incidence of abiotic disorders of broccoli // Acta Horticulturae. – 2005, vol. 697, p. 275–280

Sawan O. M., Eissa A. M., Abou-Hadid A. F. The effect of different growing media on cucumber seedling production, fruit yield and quality under greenhouse conditions // Acta Horticulturae. – 1999, vol. 491, p. 369–376

Shaw N. L., Cantliffe D. J., Funes J., Shine C. Successful beit alpha cucumber production in the greenhouse using pine bark as an alternative soilless media // HortTechnology. – 2004, vol. 14, p. 289–294

Schmilewski G. Growing medium constituents used in the EU // Acta Horticulturae. – 2009, vol. 819, p. 3345

Schroeder F. G., Sell H. Use of compost made from livestock manure as an organic substrate for cucumber (*Cucumis sativus* L.) grown in greenhouse // Acta Horticulturae. – 2009, vol. 819, p. 367–372

Siomos A. S., Beis G., Papadopoulu P. P., Barbayiannis N. Quality and composition of lettuce (cv. Plenty) grown in soil and soilless culture // Acta Horticulturae. – 2001, vol. 548, p. 445–450

Surrage V. A., Lafrenière C., Dixon M., Zheng Y. Benefits of vermicompost as a constituent of growing substrates used in the production of organic greenhouse tomatoes // HortScience. – 2010, vol. 45, p. 1510–1515

Thybo A. K., Bechmann I. E., Brandt K. Integration of sensory and objective measurements of tomato quality: quantitative assessment of the effect of harvest date as compared with growing medium (soil versus rockwool), electrical conductivity, variety and maturity // Journal of the Science of Food and Agriculture. – 2005, vol. 85, p. 2289–2296

Traka-Mavrona E., Gerasopoulos D., Pritsa T., Maloupa E. Growth, fruit yield and quality of tomato in relation to substrate and nutrient source in a soilless culture system // Acta Horticulturae. – 2001, vol. 548, p. 173–180

Tüzel I. H., Tüzel Y., Gül A., Alttunlu H., Eltez R. Z. Effect of different irrigation schedules, substrates and substrate volumes on fruit quality and yield of greenhouse tomato // Acta Horticulturae. – 2001, vol. 548, p. 285–292

Tzortzakis N. G., Economakis C. D. Impacts of the substrate medium on tomato yield and fruit quality in soilless cultivation // Horticultural Science. – 2008, vol. 35, p. 83–89

Tzortzakis N. G., Economakis C. D. Shredded maize stems as an alternative substrate medium: effect on growth, flowering and yield of tomato in soilless culture // Journal of Vegetable Science. – 2005, vol. 11, p. 57–70

Urrestarazu M., Martínez G. A., Salas M. C. Almond shell waste: possible local rockwool substitute in soilless crop culture // Scientia Horticulturae. – 2005, vol. 103, p. 453–460

Vaughn S. F., Deppe N. A., Palmquist D. E., Berhow M. A. Extracted sweet corn tassels as a renewable alternative to peat in greenhouse substrates // Industrial Crops and Products. – 2011, vol. 33, p. 514–517

Zaller J. G. Vermicompost as a substitute for peat in growing media: effects on germination, biomass allocation, yields and fruit quality of three tomato varieties // Scientia Horticulturae. – 2007, vol. 112, p. 191–199

ISSN 1392-3196
Žemdirbystė=Agriculture, vol. 99, No. 4 (2012), p. 399–408
UDK 635:631.879.4:631.878

Daržovių kokybės ir derliaus priklausomumo nuo auginimo substrato tyrimų apžvalga

M. Olle[1], M. Ngouajio[2], A. Siomos[3]

[1]Jogevos augalų selekcijos institutas, Estija
[2]Mičigano valstybinio universiteto Sodininkystės katedra, JAV
[3]Salonikų Aristotelio universiteto Sodininkystės katedra, Graikija

Santrauka

Darbo tikslas – apžvelgti mineralinio dirvožemio, neorganinių bei organinių auginimo substratų įtaką daržovių, auginamų šiltnamio sąlygomis, augimui, vystymuisi, derliui ir jo kokybei. Literatūros duomenys rodo, kad įvairių daržovių derlius būna didesnis, augalus auginant ne dirvožemyje, bet kituose substratuose. Nemažai autorių nurodo, kad pomidorai, auginti įvairiuose substratuose, pasižymėjo geresniais sausųjų medžiagų, cukringumo, tirpiųjų kietųjų dalelių, vitaminų, karotenoidų ir rūgštumo rodikliais, lyginant su augintais dirvožemyje. Tik labai mažai autorių nurodė, kad pomidorus auginant dirvožemyje gali padidėti jų rūgštumas, sausųjų medžiagų, karotenoidų ir cukraus kiekis, lyginant su kitais substratais. Daržovių augimą ir vystymąsi skatina auginimas neorganiniuose, lyginant su organiniais, substratais. Siekiant padidinti derlių, keletas autorių siūlo daržoves auginti akmens vatoje ir smėlyje. Be to, vis daugiau tyrimų duomenų atskleidžia mišrių auginimo substratų, sudarytų iš organinių bei neorganinių komponentų, naudą daržoves auginant šiltnamiuose ir siekiant didesnio jų derliaus. Daugeliu atvejų komposto pridėjimas daržovių, augintų ant organinio substrato, derliui neturėjo įtakos. Remiantis literatūros šaltiniuose pateikta informacija, sunku daryti pagrįstas išvadas apie įvairių organinių substratų įtaką daržovių cheminei sudėčiai. Kai kurie neorganiniai substratai gali pagreitinti augalų augimą, bet tai priklauso nuo naudojamo substrato. Kaip substratas zeolitas pasirodė pranašesnis už perlitą, nes paspartino gūžinių salotų augimą. Kaip teigta aptariant organines terpes, sunku daryti apibendrinančias išvadas apie neorganinių terpių įtaką daržovių cheminei sudėčiai. Tyrimų rezultatai įvairuoja, priklausomai nuo augalo bei jo cheminės sudėties ir nuo maisto medžiagų pasisavinimo iš neorganinių substratų.

Reikšminiai žodžiai: kompostas, auginimo substratas, durpės, perlitas, akmens vata, smėlis, daržovės, vermikulitas.