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The effect of substrates on yield and quality of strawberry fruits cultivated in a heated foil tunnel

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Abstract

The experiment was aimed at comparing the effects of two types of peat-coconut substrates used for strawberry (*Fragaria ananassa* Duch.) cultivation in the soilless system. The study results demonstrated a direct effect of the substrate on the yield quantity and quality of strawberry fruits. Cultivar 'Albion' proved to have the highest yield under conditions of hydroponic cultivation. A higher yield as well as increased contents of extract, sugars, organic acids, polyphenols, and anthocyanins were found in fruits from plants cultivated in the peat-coconut substrate (50:50). A different observation was made for vitamin C content, the highest content of which was determined in fruits of cultivar 'Polka' cultivated in the substrate containing 80% of peat and 20% of coconut.

Key words: fertigation, *Fragaria ananassa*, soilless cultivation.

Introduction

Soil is the basic environment for the development of plant root system and simultaneously a reservoir of nutrients and water supplying plants with elements indispensable for their growth. Soilless cultivation systems constitute an artificially created environment that is provided with precise quantities of water and nutrients (Ameri et al., 2012). The application of organic and inorganic substrates enables developing suitable conditions for root system development and for better usage of nutrients delivered with a hydrating solution (Ebrahimi et al., 2012). This translates into an increase of yield obtained from area size unit, earlier fruit harvest, easier control of pests in the crop, which simultaneously entails lower pesticide use and better quality of fruits (Paranjpe et al., 2003; Cecatto et al., 2013). What is more, the application of soilless cultivation systems reduces the spreading of weed seeds and minimises the risk of root system exposure to pathogens. Such cultivation systems have somehow become an alternative to disinfection of soil with methyl bromide (Caruso et al., 2011).

Substrate may also directly or indirectly influence the physiology of cultivated plants and their yielding (Cantliffe et al., 2001). The substrates most often applied in the soilless cultivation include peat, perlite, coconut fibre, mineral wool, and pine bark (Jafarnia et al., 2010). They are characterised by diverse physical properties such as water capacity and aeration characteristics (Cantliffe et al., 2007). It has been stated that the best substrate for soilless cultivation is peat (Lieten, 2002). However, different accessibility to a particular substrate makes that in various regions of the world attempts are undertaken to cultivate plants in other substrates which could provide good environment for plant development. Using coconut as a substrate produced good results in plant cultivation owing to its high water capacity and appropriate air conditions (Stamps, Evans 1997). The research conducted so far has pointed to the direct influence of the applied substrate on the growth and development of plants (Ercisli et al., 2005; Ayesha et al., 2011) as well as on yield quality (Yavari et al., 2008). This necessitates the search for the appropriate type of medium for the cultivation of a particular plant species.

The aim of the current research was to evaluate the influence of two types of substrate on yield and quality of fruits of five cultivars of strawberry cultivated in a heated foil tunnel.

Materials and methods

The experiment was performed in a heated foil tunnel in the cultivation gutter system. Plants of strawberry (*Fragaria ananassa* Duch.) five cultivars: 'Albion', 'Florence', 'Honeoye', 'Pegasus' and 'Polka', were planted in 24-litre bags filled with a specially prepared substrate. The following substrates were used in the experiment: a) peat + coconut fibre (80:20) and b) peat + coconut chips (50:50).

The experiment was conducted in a 3-year cycle. Each cycle lasted from February to October within the years 2013–2015. Strawberries were planted at a density of 8 plants m^{-2}, while one plot contained 16 plants. All objects of the study were conducted in four replications. The fertigation system delivered a balanced nutrient medium with electric conductivity parameters

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at 1.2 mS cm^{-1} during vegetative growth and 1.6 mS cm^{-1} during generative growth of the plants, and with pH of 5.5.

Analyses were conducted for crop yield and quality. Laboratory analyses were performed to determine the content of: extract (total soluble solids) – by refractometry (PN-EN 12143:2000. Fruit and vegetable products. Determine the content of soluble substances with refractometry), total sugars – by the Lane and Eynon method (PN-90/A-75101/07. Fruit and vegetable products. Determine the content of total sugars and nonsugar content), organic acids – by titration with phenolphthalein (PN-90/A-75101/04. Fruit and vegetable products. Determine the content of total acidity), vitamin C – using spectrophotometry method (PN-A-04019. Foodstuffs. Determine the content of vitamin C), polyphenols – using spectrophotometry method (Shahidi, Naczk, 1995) and anthocyanins – using spectrophotometry method (Wrolstad, 1993).

Results of fruit yield and analyses of the chemical composition of fruits were subjected to two-way analysis of variance (*ANOVA*), with cultivar assumed as the first factor and substrate as the second factor. Calculations were made with software *STATISTICA 12.0*. The significance of differences was assessed with the Duncan's test, at a significance level of $\alpha = 0.05$.

Results

Cultivation of strawberry in the soilless system in a heated foil tunnel proved to be a very good technological solution. Due to a reduced risk of the occurrence of such diseases as gray mould, a high yield was obtained with minimised plant protection operations. The main threat posed to the crop was infestation by strawberry powdery mildew (*Sphaerotheca macullaris*) and spider mite pest (*Tetranychus urticae*).

The fruit yield obtained was at a high level throughout the three-year study period. The lowest yield was noted for the cultivar 'Honeoye' (lower than 2 kg m^{-2}), whereas the highest one for the cultivars 'Albion' and 'Polka' (Table 1). The substrates had a great effect on the values of this parameter. The increase in fruit yield was demonstrated in plants grown in the substrate B (peat and coconut chips). The differences in yield were recorded during 3 years of the research in the cultivar 'Albion', while in the remaining cultivars, these differences were found only during one year of the study.

Table 1. Changes in total yield of strawberry fruits under substrates conditions

Cultivar	Substrate	Yield kg m^{-2}			
		2011	2012	2013	Mean
Florence	A	1.92 b	2.05 b	2.04 c	**2.00** c
	B	2.07 b	2.16 b	2.18 cd	**2.14** d
Pegasus	A	2.22 cd	2.24 bc	2.31 d-f	**2.26** ef
	B	2.26 cd	2.44 d	2.36 ef	**2.35** fg
Polka	A	2.36 de	2.38 cd	2.29 de	**2.34** fg
	B	2.35 de	2.46 d	2.48 f	**2.43** gh
Honeoye	A	1.28 a	1.35 a	1.31 a	**1.31** a
	B	1.46 a	1.52 a	1.55 b	**1.51** b
Albion	A	2.22 cd	2.18 b	2.17 cd	**2.19** de
	B	2.52 e	2.43 cd	2.46 ef	**2.47** h
Mean		**2.07**	**2.12**	**2.11**	**2.10**

Note. Substrate A – peat, coconut fibre (80:20), substrate B – peat, coconut crisps (50:50); the same letters in column marks averages which do not differ between at $\alpha = 0.05$ significance level.

The chemical composition of strawberry fruits was largely determined by cultivar-specific factors. Fruits of the cultivars 'Honeoye' and 'Pegasus' had the highest content of extract (Table 2), organic acids (Table 3) and polyphenols (Table 4).

Fruits of cultivar 'Florence' were, in turn, characterised by a high content of total sugars (Table 2), organic acids and anthocyanins (Table 4). A high content of vitamin C (Table 3) was found in fruits of cultivars 'Albion' and 'Honeoye, while cultivar 'Honeoye' was also characterised by a significant content of anthocyanins (Table 4). The substrates had a direct influence on the chemical composition of strawberry fruits. Significant differences in extract content were found in fruits of cultivars 'Albion', 'Honeoye', 'Pegasus' and 'Polka' (Table 2). Extract content in fruits obtained from plants cultivated in the substrate B was by 2–3% higher than in fruits from plants cultivated in the substrate A. Over the three-year experimental period, an increase in the content of sugars (by 0.83%), polyphenols (by 16.5%) and anthocyanins (by *circa* (ca.) 22%) and a decrease in vitamin C content (by ca. 20%) were found in fruits of cultivar 'Polka' cultivated in the substrate B. The content of organic acids was at 1.1–1.3% in fruits of particular cultivars; however, an increase in the content of these acids and additionally anthocyanins was found in fruits of cultivar 'Florence' cultivated in the substrate B (by 0.08%). A different nature of changes in the chemical composition was found in fruits of cultivar 'Honeoye'. An increase in the content of organic acids (by 0.15%) and (occasionally) anthocyanins (by 19.7% in the 1st year and 17.5% in the 2nd year) and vitamin C (by 4% in the

Table 2. Changes in extract and total sugar content in strawberry fruits under substrate conditions

Cultivar	Substrate	Extract, °Brix				Total sugar %			
		2011	2012	2013	Mean	2011	2012	2013	Mean
Florence	A	11.92 bc	11.75 b	11.87 d	**11.85** cd	7.48 d	7.40 de	7.57 e	**7.48** de
	B	11.67 b	11.92 bc	11.67 c	**11.75** c	7.63 d	7.61 f	7.59 e	**7.61** e
Pegasus	A	11.92 ab	12.03 b-d	11.87 d	**11.94** d	7.70 d	7.59 f	7.60 e	**7.63** e
	B	12.33 cd	12.27 cd	12.30 f	**12.30** f	7.63 d	7.54 ef	7.60 e	**7.59** e
Polka	A	11.92 bc	12.07 b-d	11.93 d	**11.97** d	6.43 a	6.40 a	6.72 ab	**6.52** a
	B	12.42 d	12.33 d	12.37 f	**12.37** f	7.44 d	7.35 d	7.27 d	**7.35** d
Honeoye	A	12.17 cd	12.10 b-d	12.13 e	**12.13** e	6.75 a-c	6.59 b	6.77 bc	**6.70** b
	B	12.50 d	12.42 d	12.33 f	**12.42** f	6.81 bc	6.72 bc	6.62 a	**6.72** b
Albion	A	10.67 a	10.60 a	10.63 a	**10.63** a	6.95 c	6.83 c	6.91 c	**6.90** c
	B	10.83 a	10.85 a	10.85 b	**10.84** b	6.50 ab	6.55 ab	6.70 ab	**6.58** ab
Mean		**11.83**	**11.83**	**11.79**	**11.82**	**7.13**	**7.06**	**7.13**	**7.11**

Explanations under Table 1

Table 3. Changes in organic acids and vitamin C content in strawberry fruits under substrate conditions

Cultivar	Substrate	Organic acids %				Vitamin C mg 100 g^{-1}			
		2011	2012	2013	Mean	2011	2012	2013	Mean
Florence	A	1.20 c-e	1.19 cd	1.21 bc	**1.20** cd	73.58 bc	72.59 cd	70.82 cd	**72.33** c-e
	B	1.27 fg	1.27 ef	1.31 e	**1.28** f	71.73 b	70.73 bc	68.81 bc	**70.42** b-d
Pegasus	A	1.23 d-f	1.20 cd	1.25 c-e	**1.23** de	70.70 b	69.39 a-c	69.31 c	**69.63** bc
	B	1.26 e-g	1.21 de	1.29 de	**1.25** ef	69.60 ab	67.68 ab	66.95 b	**68.08** b
Polka	A	1.19 cd	1.18 cd	1.18 a-c	**1.18** cd	80.60 c	78.28 e	72.60 de	**77.16** f
	B	1.20 c-e	1.19 cd	1.24 cd	**1.21** de	62.84 a	66.08 a	63.10 a	**64.01** a
Honeoye	A	1.30 g	1.29 f	1.30 de	**1.30** f	77.20 bc	73.66 cd	74.78 f	**75.21** ef
	B	1.17 bc	1.14 bc	1.15 ab	**1.15** bc	75.53 bc	73.61 cd	71.85 de	**73.66** d-f
Albion	A	1.09 a	1.08 a	1.12 a	**1.10** a	77.27 bc	76.87 de	73.73 ef	**75.96** ef
	B	1.19 ab	1.09 ab	1.12a	**1.13** ab	74.10 bc	73.19 cd	70.49 cd	**72.59** c-e
	Mean	**1.21**	**1.18**	**1.22**	**1.20**	**73.31**	**72.21**	**70.24**	**71.90**

Explanations under Table 1

Table 4. Changes in polyphenols and anthocyanins content in strawberry fruits under substrate conditions

Cultivar	Substrate	Polyphenols mg 100 g^{-1}				Anthocyanins mg 100 g^{-1}			
		2011	2012	2013	Mean	2011	2012	2013	Mean
Florence	A	1400 c	1406 c	1405 c	**1404** c	42.66 d	42.23 c	42.28 b-d	**42.39** cd
	B	1456 cd	1437 cd	1448 c	**1447** d	46.09 ef	47.07 d	46.91 ef	**46.69** d
Pegasus	A	1576 e	1534 e-g	1515 d	**1542** e	18.33 a	19.53 a	31.39 a	**23.08** a
	B	1563 e	1589 g	1633 e	**1595** f	21.84 a	21.60 a	33.00 a	**25.48** ab
Polka	A	1256 b	1254 b	1243 b	**1251** b	29.01 b	30.03 b	41.55 bc	**33.53** bc
	B	1470 cd	1457 c-e	1447 c	**1458** d	39.36 c	38.66 c	44.70 de	**40.91** cd
Honeoye	A	1568 e	1546 fg	1536 d	**1550** e	47.39 f	48.80 d	50.93 g	**49.04** d
	B	1525 de	1495 d-f	1537 d	**1519** e	39.60 cd	41.52 c	48.21 fg	**43.11** cd
Albion	A	1072 a	1078 a	1082 a	**1077** a	30.14 b	32.50 b	44.44 c-e	**35.69** c
	B	1050 a	1046 a	1076 a	**1057** a	28.72 b	30.76 b	40.54 b	**33.34** bc
	Mean	**1394**	**1384**	**1392**	**1390**	**34.31**	**35.27**	**42.39**	**37.32**

Explanations under Table 1

3rd year) was found in fruits of this cultivar cultivated in the substrate A. Simultaneously, it was found that the content of sugars increased (by 0.32%) in fruits of cultivar 'Albion' obtained from plants cultivated in the peat and coconut substrate A (80:20 v/v).

Discussion

The results obtained from the conducted research demonstrated that yielding and quality of strawberry fruit were determined not only by the cultivar factor, but also by the type of substrate used for strawberry cultivation. Water capacity, proper density and porosity of the substrate play a decisive role for its usability for cultivation (Ameri et al., 2012). The substrate containing 50% of coconut chips and 50% of peat brick showed better properties for strawberry cultivation, which translated into the quantity and quality of the fruit yield obtained. Results achieved confirm findings of other authors, who demonstrated substantial differences in the assessed parameters of plants as affected by substrate type (Ercisli et al., 2005; Wang, Millner, 2009; Jafarnia et al., 2010; Roosta, Afsharipoor, 2012; Martinez et al., 2013). Research conducted by many authors (Ameri et al., 2012; Ebrahimi et al., 2012) point to higher yields of strawberries cultivated in the substrate containing coconut. A study conducted by Ghazvini et al. (2007) demonstrated also an increase in plant yield in response to an increasing perlite to zeolite ratio in the cultivation medium. The extract includes organic compounds dissolved in a cell sap. The higher extract content determined in the fruits of plants cultivated in the peat-coconut substrate (50:50) seems to confirm better physical properties of the coconut-containing substrate. Research conducted by Ghazvini et al. (2007) demonstrated that increasing perlite to zeolite ratio in the cultivation medium contributed to the increase in extract content in strawberry fruits. Sugars constitute a direct product of photosynthesis. The degree of fruit ripeness determines their contents, which when combined with organic acids influence the taste of fruits (Perez et al., 1997). The increased contents of this component in strawberry fruits cultivated in the substrate with increased coconut content were also confirmed in literature (Ayesha et al., 2011). The use of compost in the cultivation substrate contributed also to the increase in sugar content in fruits (Wang, Lin, 2002). Strawberries are a rich source of vitamin C, which is a natural antioxidant, its content in strawberries exceeds several times that found in apples and grapes (Santos, Chandler, 2009). It was shown that even a small (20%) content of coconut in the substrate A had a beneficial influence on vitamin C accumulation in strawberry fruits. It confirms findings reported by other authors (Ayesha et al., 2011). The use of a substrate containing a combination of humus from cypress leaves and mineral soil in research of Yavari etal. (2008) also indicated a beneficial influence on vitamin C content in fruits. However, Voca et al. (2006) observed a negative impact of soilless cultivation on the content of L-ascorbic acid in strawberry fruits. Polyphenols and anthocyanins also exhibit biologically-active properties, and even anti-mutagenic ones. Their increased contents in fruits obtained from plants cultivated in the substrate B confirm that this substrate provides better conditions for plant development and assimilation of the assessed compounds. The research performed by other authors has proved that the content of these compounds is also affected by the cultivation system (Bojarska et al., 2006; Fernandes et al., 2012).

Conclusions

1. The results of the study enable us to conclude that the applied substrates directly influenced the yield of strawberry fruits cultivated in the soilless system.

2. Better properties for strawberry cultivation were ensured by the substrate containing 50% of peat and 50% of coconut chips. This substrate positively influenced the content of extract, organic acids, sugars, polyphenols and anthocyanins in strawberry fruit.

3. Accumulation of vitamin C in strawberry fruits was determined by substrate type, whereas its higher contents were found in the fruits of plants cultivated in the substrate with a lower content of coconut.

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Substratų įtaka braškių uogų, augintų šildomame folijos tunelyje, derliui ir kokybei

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Santrauka

Bandymu siekta palyginti dviejų tipų substratų – durpių ir kokoso riešutų – įtaką braškėms, jas auginant bežemėje sistemoje. Tyrimo rezultatai parodė tiesioginę substratų įtaką braškių uogų derliui ir kokybei. Veislės 'Albion' braškių didžiausias derlius gautas esant hidroponikos sąlygoms. Didesnis derlius ir didesni kiekiai ekstrakto, cukrų, organinių rūgščių, polifenolių bei antocianinų buvo nustatyti uogose augalų, augintų durpių ir kokoso riešutų substrate (50:50). Didžiausias kiekis vitamino C buvo nustatytas veislės 'Polka' uogose, kai augalai auginti substrate, sudarytame iš 80 % durpių ir 20 % kokoso riešutų.

Reikšminiai žodžiai: bežemis auginimas, fertigacija, *Fragaria ananassa*.