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YIELD AND QUALITY OF GREENHOUSE TOMATO FRUIT GROWN IN RAPE STRAW SUBSTRATES

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Abstract. Studies were conducted with tomato of Admiro F_1 cultivar grown in greenhouse in the years 2008 and 2009. Four substrates were applied: 1) rape straw, 2) rape straw + high peat (3 : 1 v:v), 3) rape straw + pine bark (3 : 1 v:v), 4) rockwool (100 × 20 × 7.5 = 15 dm^3). Straw, cut into pieces, (2–3 cm), were placed in plastic boxes (height of the box ca. twice large as width) of the capacity of 15 dm^3. In each box/slab there grew two plants. The experiment was conducted using the complete randomization method in seven repetitions. Dripping fertigation was applied in a closed system without nutrient solution recirculation. Daily nutrient solution consumption was once up to 4.2 dm^3 in 10–12 doses with about 20% overflow. In the conducted studies it was demonstrated that the cut rape straw is a very good substratum for greenhouse grown tomato. Higher fruit yields were obtained from growing in rape straw + pine bark substratum compared to rockwool, and the differences were not significant. The dry matter content in fruit grown in organic substrata was significantly higher compared to rockwool. The content of N-total in fruit grown in rockwool was significantly lower compared to organic substrata. During tomato vegetation about 60% rape straw was mineralized.

Key words: substrates, tomato, yield, dry mater, vitamin C, sugar

INTRODUCTION

The applicability of mineral substrata, including mainly rockwool and perlite for greenhouse grown plants has been worked out. Considering the costs of their production and management as post-production waste, the plant growing area in these substrata decreases. In recent years many studies have been conducted on using various organic materials in greenhouse growing, which are most frequently waste (cut rye and wheat straw, wood, sawdust, coconut fiber) as substrata for vegetables and ornamental plants [Nurzyński 2006a, b, Mahamud and Manisah 2007, Dorais et al. 2007, Ehret and Helmer 2009]. Some organic waste should be composted in oxygen conditions with slight

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addition of peat. The materials coming from trees and shrubs slowly get decomposed and thus the structure of compost is good. [NiChualain et al. 2011, Raviv 2011 a, b].

The issues of obtaining and applying the organic substrates in greenhouse cultivations constituted the subject of two recent international conferences:I International Conference on Organic Greenhouse Horticulture (11–14 Oct. 2010 in the Netherlands) and International Symposium on Growing Media, Composting and Substrate Analysis (17–21 Oct. 2011 in Spain). In many papers it was emphasized that in greenhouse growing organic substrata will predominate. The market for main greenhouse vegetable crops (tomato, cucumber, peppers) becomes international and therefore it is planned to work out uniform principles of cultivation, also with reference to the applied substrata, at least for the EU countries [Blom 2011, Van der Lans et al. 2011].

During the Symposium in Spain the possibility was considered of using many organic materials for preparing substrata, depending on agricultural crops in particular regions. And peat is perceived as a possible slight addition to organic waste materials. The authors of the papers demonstrated that a good substratum is the utilized wood waste also used as an alternative aggregate in peat. To maintain compost ground bamboo, rice straw, sawdust from various tree species, coconut fiber and fresh rice hulls were used. Adding such compost to peat (even up to 50%) a very good substratum is obtained for tomato and other plants grown in greenhouse.

Interesting results obtained from tomato growing should be emphasized. There the substrata were rye straw, wheat straw cut into pieces [Nurzyński 2006a, b], and slabs made of shredded rye straw [Dyśko et al. 2009]. High yield was obtained like from cultivation in rockwool.

The aim of the presented paper were studies on growth and yielding of tomato grown in greenhouse in the substrata of cut rape straw, mixture of rape straw with high peat, pine bark and rockwool.

MATERIAL AND METHODS

Studies were conducted in the greenhouse of Department of Soil Cultivation and Fertilization of Horticultural Plants, University of Life Sciences in Lublin. The tomato of Admiro F_1 cultivar was grown in the period from 10^{th} February to 21st October 2008 and from 4^{th} February to 15^{th} October 2009 for 22 clusters at the density of 2.4 plants per 1 m^2. The following substrata were examined: 1) rape straw, 2) rape straw + high peat (3:1 v:v), 3) rape straw + pine bark (3:1 v:v), 4) rockwool (100 × 20 × 7.5 cm = 15 dm^3). Straw was cut into pieces (2–3 cm) and placed in rectangular boxes 14 cm high, bottom width: 8 cm and capacity 15 dm^3. During the growing period about 60% straw has been decomposed. Evaluation of straw decomposition was done by comparing the weight of air dry weight of straw before the experience with the mass after the experiment (after removal of roots). In each box/slab two plants grew. The experiments were conducted with the use of complete randomization method in seven repetitions.

Drip fertigation method was applied in closed system without recirculation of nutrient solution that contained ($mg \cdot dm^{-3}$): N-NO_3 – 210, P – PO_4 – 54, K – 340, Ca – 250, Mg – 80, Cl – 20, S-SO_4 – 150, Fe – 2.0; Mn – 0.95; B – 0.54; Cu – 0.09; Zn – 0.56;

Mo – 0.09. In the period of high temperatures the nutrient solution was applied in the daily amount of about 4.2 dm^3 per plant in 10–12 single doses with 20% nutrient solution effusion from the box/slab.

Bombus terrestris used for plant pollination, Greenhouse Whitefly (*Frialeurodes vaporariorum*) was biologically controlled with *Encarsia formosa*.

The fruit was collected twice a week. Vitamin C was determined in fruit with the use of Tillmans's method, sugars according to Schorl-Rogenbogen, N-total using Kiejdahl's method (Tecator), P- colorimetrically with ammonium vanadomolybdate (Nicole Evolution 300), K, Ca, Mg using ASA method (Perkin Elmer, Analyst 300). For the analyses 10 ripe fruits were sampled, of the diameter of 7–9 cm, of the weight of 200 g in three repetitions. In the substrata (solution from the root zone) N-NO_3 was determined with the use of Bremner's distillation method in Starck's modification, EC – conductometrically. Statistical elaboration of results was conducted using the method of variance analysis on mean values, applying Tukey's test for assessing differences, at significance level of $\alpha = 0.05$.

RESULTS

During tomato vegetation (33 weeks) cut rape straw got systematically decomposed and after the experiments had been completed about 40% of it remained. This straw does contain all macro- and microelements that plants need, but in small amounts. Mean content equals (% d.m.): N-total – 0.71, P – 0.09, K – 1.10, Ca – 1.80, Mg – 0.11, Cl – 0.05, S-SO_4 – 0.18 and ($mg \cdot dm^{-3}$) Fe – 150, Mn – 75, Zn – 35, B – 15, Cu – 8, Mo – 0.05.

In connection with straw decomposition, to improve the physical properties of substratum high peat (25%) and pine bark were added.

In all the objects high fruit yield was obtained, on average from two years on one plant 16.58 kg (tab. 1), which, converted to 1 m^2 of area equals 39.80 kg.

Comparing total fruit yield from the examined objects no significant differences were found. From growing in organic substrata (straw, straw + peat, straw + pine bark) the mean yield equaled 16.67 kg from one plant, and in rockwool 16.32 kg, and the highest yield was obtained in straw + pine bark (16.81 kg) substratum. Similar dependences were demonstrated in marketable yield.

During the intense mineralization of straw, especially at the beginning of growing, microbes take up greater amounts of mineral components, mainly of nitrogen. In the experiments performed no differences were observed in growth of plants grown in organic substrata and rockwool. And the analysis of EC values and the contents of N-NO_3 in the substrata indicate low values in March and April (fig. 1 and 2). It has to be added that at the beginning of growing tomato needs the most nutrients, which is confirmed by the comparison of EC values and the contents of N-NO_3 in the organic substrata and in rockwool in the presented graphs.

The normal growth of plants at small nutrient contents in the substrata is possible with the application of fertigation, because in this system the nutrient solution is added to plants 8–10 times a day and twice at night.

Table 1. The yield of tomato fruits (kg·plant^{-1}), dry matter (%), vitamin C (mg·100 g^{-1} fr. w.) sugars (% fr. w.) in 2008 and 2009
Tabela 1. Plon owoców pomidora (kg·roślina^{-1}), zawartość suchej masy (%), witaminy C (mg·100 g^{-1} św. m.), cukrów (% św. m.) w roku 2008 i 2009

Substrate Podłoża	Years Lata	Total yield Plon ogółem	Marketable yield Plon handlowy	Dry matter Sucha masa	Vitamin C Witamina C	Total sugars Cukry ogółem
Rape straw Słoma rzepakowa	2008	16.62	14.85	6.64	17.76	2.21
	2009	16.64	14.64	5.43	25.85	2.39
	mean średnia	16.63a	14.74a	6.03a	21.80a	2.30a
Rape straw + peat Słoma rzepakowa + torf	2008	16.45	14.50	5.14	18.87	2.31
	2009	16.69	14.69	5.48	23.60	2.32
	mean średnia	16.57a	14.59a	5.31b	21.23a	2.31a
Rape straw + pine bark Słoma rzepakowa + kora sosnowa	2008	16.71	14.54	5.30	17.50	2.34
	2009	16.92	14.89	5.80	23.55	2.56
	mean średnia	16.81a	14.71a	5.55b	20.52a	2.45a
Mean for organic substrate Średnia dla podłoży org.		16.67a	14.68a	5.63b	21.18a	2.45a
Rockwool Wełna mineralna	2008	16.68	14.47	1.08	17.76	2.64
	2009	15.97	14.05	4.90	22.48	2.39
	mean średnia	16.32a	14.26a	4.99c	20.12a	2.51a

Note: Means in the column followed the same letter are not significant different at α = 0.05
Średnie w kolumnach oznaczone tą samą literą nie różnią się istotnie przy α = 0,05

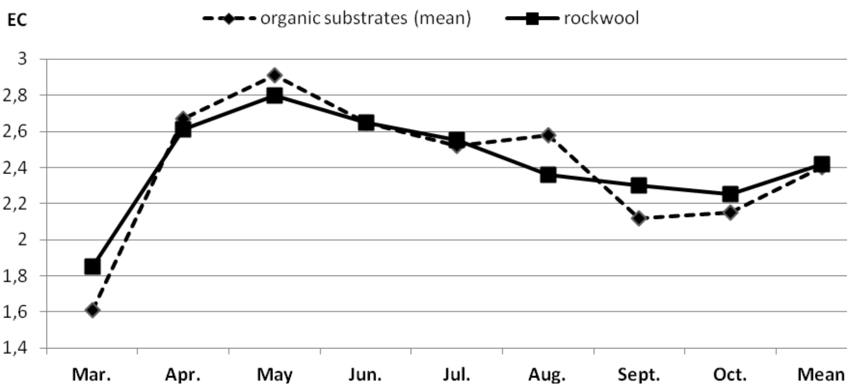

Fig. 1. EC in substrates (mS·cm^{-1}) during vegetation season. Mean 2008–2009
Rys. 1. Wartość EC w podłożach (mS·cm^{-1}) w okresie wegetacji. Średnie 2008–2009

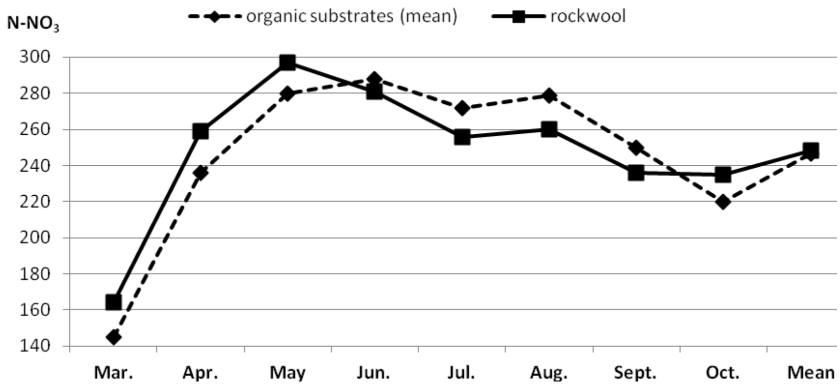

Fig. 2. The N-NO_3 content in substrates (mg·dm^{-3} of solution from the root zone) during vegetation season. Mean 2008–2009
Rys. 2. Zawartość N-NO_3 w podłożach (mg dm^{-3}roztworu ze strefy korzeniowej) w okresie wegetacji. Średnie 2008–2009

Table 2. The nutrients content of tomato fruit (% d.m.) in year 2008 and 2009
Tabela 2. Zawartość N, P, K, Ca, Mg w owocach pomidora (% s.m.) w roku 2008 i 2009

Substrate Podłoża	Years Lata	N-total N-ogółem	P	K	Ca	Mg
Rape straw Słoma rzepakowa	2008	2.12	0.4	4.38	0.08	0.11
	2009	2.21	0.39	2.63	0.12	0.13
	mean średnia	2.16a	0.42a	3.50a	0.10a	0.12a
Rape straw + peat Słoma rzepakowa + torf	2008	1.99	0.42	4.29	0.07	0.10
	2009	2.24	0.39	2.76	0.13	0.15
	mean średnia	2.11b	0.40a	3.52a	0.10a	0.12a
Rape straw + pine bark Słoma rzepakowa + kora sosnowa	2008	1.97	0.46	4.65	0.05	0,11
	2009	2.08	0.43	2.83	0.12	0.14
	mean średnia	2.02c	0.44a	3.74b	0.08a	0.12a
Mean for organic substrate Średnia dla podłoży org.		2.10b	0.42a	3.59b	0.09a	0.12a
Rockwool Wełna mineralna	2008	1.96	0.46	4.13	0.07	0.10
	2009	2.19	0.46	3.14	0.12	0.17
	mean średnia	2.07bc	0.46b	3.63b	0.09a	0.13a

Note: see Table 1

An important indicator of tomato fruit quality is the dry matter content, as well as the contents of vitamin C, sugars and mineral components (tab. 1). The dry matter content was on average 5.31%, it was significantly higher from plants grown in organic substrata (5.63%) compared to rockwool (4.99%). This also means the differences in fruit dry matter yield. For instance, in the year 2009 the yield from cultivation in rape straw + pine bark substratum equaled 16.92 kg, and in rockwool it was 15.97 kg from a plant. The difference is slight, but after conversion to dry fruit weight it equals respectively: 0.99 kg and 0.79 kg from one plant. Now the difference is already significant.

The contents of vitamin C in fruit ranged from 17.50 to 25.85 mg· 100 g^{-1} f.w. and it was higher from cultivation in the year 2009 compared to 2008,whereas the examined substrata had no significant effect upon that value. Similarly, no significant influence of examined substrata was found upon sugar content.

The contents of N, P, K, Ca, Mg in fruit seem to be interesting (tab. 2). In conversion to dry matter high contents of nitrogen, phosphorus and potassium were obtained. Comparing the obtained values, from growing in organic substrata significantly more nitrogen and less phosphorus was obtained than in rockwool. The differences in potassium and magnesium contents were slight, and not significant. On the basis of nitrogen content it should be concluded that tomato fruit is abundant in protein.

Tomato fruits contain small amounts of calcium and this component is very important for this plant. When its content decreases below ca 0.05% Ca in d.m., then blossom-end rot disease occurs on the fruits. Such fruit is inedible. In the conducted studies this disease did not occur, in spite of the fact that in the year 2008 (rape straw + pine bark) the fruit contained only 0.05% Ca in d.m.

DISCUSSION

Considering the economical reasons as well as the protection of natural environment, instead of mineral substrata (rockwool, perlite), whose recycling causes problems, organic substrata or mixtures of organic and mineral materials are used more and more frequently. Thanks to the possibility of applying fertigation in greenhouse growing, the organic materials can be different and most often it is waste, a lot of which can be found in the nearest region. Scientific studies on the subject are conducted in many research institutes.

The results obtained in the conducted studies on tomato growing in greenhouse in substrata of rape straw, straw + high peat and pine bark should be regarded as interesting.

High fruit yield was obtained and it did not differ significantly compared to rockwool. This is confirmed by the results of other authors' studies obtained in growing tomatoes in various organic substrata, e.g. wood fibre, coconut fibre, fresh rice hulls, crushed sugarcane, peanut hull [Fernandes et al. 2007, Gachukia and Evans 2008, Domeno et al. 2009]. These materials occur mainly in particular regions, and their transport to further distances is not always economically justified.

Substrata are also prepared as mixtures of organic waste materials, most often with peat and waste materials should be composted in oxygen conditions, which is connected with additional costs [Raviv 2011 a, b].

Good results were obtained with the use of organic waste first as fuel for heating water. Then the obtained ash was mixed with peat in the amount of even up to 40%. The substratum prepared like this is very good for tomato grown in containers, in a greenhouse. [Evans et al. 2011].

Rape straw, however, is commonly available, it should only be cut into pieces of 2–3 cm, it does not require deacidification, composting, disinfection and after cultivation, as post-production waste it does not pollute the natural environment. Rape straw substratum is very cheap.

Each substratum has to have optimal water-air conditions. Therefore, we add slowly decomposing materials to every substratum, e.g. feather fiber, pumice [Evans and Vancey 2007, Tzortzakis and Economakis 2007].

In the conducted studies, due to rape straw decomposition, adding high peat and pine bark had an advantageous effect. Fruit yields did not significantly differ, but fruit cultivated in organic substrata contained more dry matter, vitamin C and nitrogen, compared to rockwool, which is confirmed by others [Kowalczyk et al. 2011 a, b].

Because of the significant mineralization of cut straw during vegetation of tomato, the containers for this substratum have to be about twice as high as wide and then the correct water-air ratio in the substratum will be maintained. Placing cut straw e.g. in foil, shaping it like a rockwool mat (20 cm wide and 7.5 cm high) gives definitely worse conditions of root and overground parts development, and the yield will always be higher compared to e.g. rockwool. [Nurzyński 2002, Kaniszewski et al. 2010].

Enriching greenhouse air with CO_2 positively affects the growth and yielding of plants grown in greenhouse. The atmospheric air contains about 350 ppm CO_2, whereas in greenhouse air there should be even 900–1000 ppm of CO_2, which is used in the process of photosynthesis [Elings et al. 2007, Hao et al. 2008, Stanghellini et al. 2009].

The organic substrata undergo mineralization during vegetation. Rape straw applied as substratum in the conducted studies with tomato was decomposed in about 60%. This means that the plants obtained some nutrients and substantial amounts of CO_2, which is taken up by their leaves and used in the process of photosynthesis.

Products from organic vegetable growing in greenhouse and polytunnels are in high demand. To obtain high quality yield a range of conditions must be met, such as the application of appropriate fertilizers, especially nitrogen and phosphorus, as well as substrata prepared from organic materials [Voogt et al. 2011].

The hitherto studies indicate that horticultural cultivations can be profitable. There are possibilities of applying cheap substrata, growing in polytunnels or unheated glasshouses, as well as of selecting appropriate species to be grown in the same year [Schmutz et al. 2011].

On the basis of the obtained results it can be stated that the examined organic substrata, especially rape straw + pine bark meet the conditions for a very good organic substrate for greenhouse grown tomato.

CONCLUSIONS

1. Cut rape straw is a very good substratum for greenhouse grown tomato. Higher fruit yields were obtained from growing in rape straw + pine bark substratum compared to rockwool, but the differences were not statistically proved.

2. The dry matter content in fruit grown in organic substrata was significantly higher compared to rockwool.

3. The content of N-total in fruit grown in rockwool was significantly lower compared to organic substrata.
4. During tomato vegetation about 60% of rape straw was mineralized.

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PLON I JAKOŚĆ OWOCÓW POMIDORA SZKLARNIOWEGO UPRAWIANEGO W PODŁOŻU ZE SŁOMY RZEPAKOWEJ

Streszczenie. Badania przeprowadzono z pomidorem odmiany Admiro F_1 uprawianym w szklarni w roku 2008 i 2009. Zastosowano cztery podłoża: 1) słoma rzepakowa, 2) słoma rzepakowa + torf (3:1 v:v, 3) słoma rzepakowa + kora (3:1 v:v), 4) wełna mineralna (100 × 20 × 7,5 = 15 dm^3). Słomę pociętą na kawałki (2–3 cm) umieszczono w skrzynkach plastikowych (wysokość skrzynki około dwa razy większa od szerokości) o pojemności 15 dm^3. W każdej skrzynce/macie rosły dwie rośliny. Doświadczenie przeprowadzono metodą kompletnej randomizacji w siedmiu powtórzeniach. Stosowano fertygację kroplową w układzie zamkniętym bez recyrkulacji pożywki. Zużycie pożywki na dobę wynosiło jednorazowo do 4,2 dm^3 w 10–12 dawkach z około 20% przelewem. W przeprowadzonych badaniach wykazano, że pocięta słoma rzepakowa jest bardzo dobrym podłożem dla pomidora uprawianego w szklarni. Wyższe plony owoców otrzymano z uprawy w podłożu słoma rzepakowa + kora w porównaniu z wełną mineralną, przy czym różnice nie były statystycznie istotne. Zawartość suchej masy w owocach z uprawy w podłożach organicznych była istotnie wyższa w porównaniu z wełną mineralną. Zawartość N-ogółem w owocach z uprawy w wełnie mineralnej była istotnie niższa w porównaniu z podłożami organicznymi. W okresie wegetacji pomidora około 60% słomy rzepakowej zostało zmineralizowane.

Słowa kluczowe: podłoża, plon, sucha masa, witamina C, cukry, pomidor

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