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YIELDING AND CHEMICAL COMPOSITION OF „HONEOYE" CULTIVAR STRAWBERRIES DEPENDING ON THE KIND OF SUBSTRATUM AND NITROGEN DOSE

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Abstract. Growing strawberries under covers in substrates allows to eliminate the application of soil decontamination, which is costly and harmful for the environment. At the same time it guarantees obtaining a higher and better quality yield, as compared to the traditional ground cultivations. In the years 2005–2006 studies were conducted, aiming at determining the effect of three kinds of substratum (peat, peat mixed with composted pine bark in the proportion of 1:1, peat mixed with composted pine sawdust in the proportion of 1:1) and differentiated nitrogen dose (140 or 210 mg $N \cdot dm^{-3}$) upon yielding, chemical composition of leaves and fruit of strawberry (*Fragaria* × *ananasa* Duch.) of 'Honeoye' cultivar, grown in an unheated foil tunnel. The total and marketable yield quantity of strawberry fruit grown in peat and in peat with pine bark did not differ significantly. Lower total (407,1 $g \cdot plant^{-1}$) and marketable fruit yield (264,6 $g \cdot plant^{-1}$) was reported when plants were grown in peat mixed with sawdust. Plants grown in peat mixed with sawdust gave fruit with significantly lower unit weight compared to plants growing in the remaining substrates. The studies did not demonstrate a significant effect of differentiated nitrogen fertilization upon strawberry yielding. In the leaves of plants fertilized with nitrogen dose of 200 mg $N \cdot dm^{-3}$ significantly more nitrogen was found, as well as less calcium, compared to plants fertilized with a smaller dose of this component. In the fruits of strawberry fertilized with a larger nitrogen dose, significantly more nitrates (V), total nitrogen and potassium were reported and less dry matter, extract and calcium compared to fruit collected from plants fertilized with nitrogen dose of 140 mg $N \cdot dm^{-3}$.

Key words: soilless cultivation, organic substrate, nitrogen fertilization, chemical composition of plants

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INTRODUCTION

Growing strawberries under covers in substrates allows to eliminate the application of soil decontamination, which is costly and harmful for the environment, at the same time guaranteeing higher and better quality yield, compared to the traditional ground crops [Lopez-Medina et al. 2004, Recamales et al. 2007]. The predominant substratum in growing strawberries under covers is peat. The increasing costs related to using this substratum enhance seeking alternative solutions [Kemppainen et al. 2004, Lieten et al. 2004]. A way that allows for significant limitation of consuming the expensive and more scarce peat is mixing that material with easily accessible and cheaper components, which are bark and sawdust [Lieten et al. 2004, Rumpel 1998]. The barrier that significantly limits broader application of mixed substrates with bark and sawdust is lack of detailed fertilization recommendations [Jarosz and Konopińska 2006, Pudelski 1996]. Due to differentiated physicochemical properties of mixed substrates with peat, bark and sawdust, what seems to be most important in using them, is the appropriate fertilization of plants with nitrogen, which is regarded as the main factor that determines the size and quality of strawberry fruit [Jarosz and Konopińska 2006, Nestby et al. 2004].

The undertaken studies were aimed at explaining the effect of the kind of substratum and nitrogen dose upon yielding and chemical composition of 'Honeoye' cultivar strawberry leaves and fruits.

MATERIAL AND METHODS

The experiment was performed in the years 2005–2006, in an unheated foil tunnel, located on the premises of the Experimental Farm Felin. The experimental plant was strawberry (*Fragaria* × *ananassa* Duch) of 'Honeoye' cultivar, grown in containers of the capacity of 5 dm^3 in ten repetitions. A repetition was a container with one plant. The experiment was established in complete randomization system on the 9th day of September 2004 and on the 5th day of September 2005. In the studies fresh (green) strawberry seedlings of the size A+ were used. The substratum was transitional peat, mixed with composted pine bark in volume proportion of 1 : 1 and transitional peat mixed with composted pine sawdust in volume ratio of 1 : 1. The substrata reaction was regulated before planting to pH 5.8. During the studies the reaction remained within the range of pH 5.5–6.0. Additionally, the level of nitrogen fertilization was differentiated in the studies, by supplying this component to the plants in the dose of : N_1 – 140 $mg \cdot dm^{-3}$ or N_2 – 210 $mg \cdot dm^{-3}$. The quantities of the remaining components supplied to plants were equal in all the objects and it was ($mg \cdot dm^{-3}$): 140 P, 250 K, 100 Mg. Microelements were applied in the amount recommended for peat substratum [Pudelski 1998]. Nutrients were supplied to plants in the form of water solution of the following fertilizers: ammonium saltpeter – 34% N, monobasic potassium phosphate: 22.9% P and 28.2% K, potassium sulfate: 41.5% K, magnesium sulfate: 15.6% Mg. Before planting the plants the contents of nutrients in substrata had been adjusted to the assumed levels, considering their original composition. During vegetation the components were supplemented every two weeks. During the studies each plant was supplied with 8.4 or 12.6 g N, 8.4 g P, 15.0 g K and 6.0 g Mg. Because of high calcium contents in the water used for plant watering (140–160 mg·dm^{-3}) no additional fertilization with this component was applied. Plants were watered by dripping, with the use of Galcon time controller, at daily water flow of 150–250 cm^3 for one plant. Strawberry flowers were pollinated by bumblebee (*Bombus terrestris*). Plant protection procedures were conducted in accordance with the recommendations in force. Experiments were liquidated after the end of fruit harvest (23 VI 2005 and 27 VI 2006).

Fruit harvests, lasting from 12 V to 20 VI 2005 and from 17 V to 26 VI 2006, were performed every two days. Fruits were counted and weighed, determining the total yield, the marketable yield an mean weight of one fruit (PN-R-75535:1996)

The substratum analysis was performed before the establishment of experiment and in the vegetation season every four weeks. The determinations of N-NH_4, N-NO_3, P-PO_4, K, Ca and Mg contents were performed after the extraction of a substratum sample (20 cm^{-3}) 0.03 M CH_3COOH. The ammonium and nitrate nitrogen were determined by means of Bremner's method (modified by Starck), phosphorus – colorimetrically with ammonium vanadomolybdate, potassium, calcium and magnesium – using the ASA method (Perkin-Elmer Analyst 300).

Leaves for the analyses were sampled during full flowering and in the middle of plant fruiting. The indicator part was the youngest fully developed leaf. In the plant material total nitrogen was determined (with the use of Kjeldahl's method) and, after burning in a stove (temp. 550ºC) – phosphorus, potassium, calcium and magnesium – using the same methods as in substratum analysis.

Fruits were sampled for analysis in the phase of harvest maturity – half-way through fructification. Dry matter was determined in the fresh material (using the dryer method), as well as extract (refractometrically) and nitrates (V) using test strips (RQ-Flex, Merck). After drying the material the following were determined: total nitrogen (by means of Kjeldahl's method), phosphorus, potassium, calcium and magnesium – with the same methods as when analyzing leaves.

The statistical elaboration of results was performed using the method of variance analysis on mean values, applying Tukey's test for difference assessment, at the significance level $\alpha = 0.05$. The presented results are mean values from the two study years.

RESULTS AND DISCUSSION

The main factors determining yield quantity and quality of plants grown in the soilless system include the kind of used cultivating substratum and the level of supplying plants with nutrients [Jarosz and Konopińska 2006, Nestby et al. 2004]. The application of mixed organic substrata with differentiated shares of peat, bark or sawdust requires clarifying fertilizing recommendations because of the possibility of biological sorption of nutrients. This problem concerns mainly nitrogen [Markiewicz et al. 2008, Jarosz and Konopińska 2010].

The statistical analysis of the results obtained in the conducted studies did not reveal any significant differences in the total and marketable fruit yield of strawberry grown in peat and peat mixed with pine bark (tab. 1). The obtained results are consistent with

Table 1. Yielding of 'Honeoye variety strawberries depending on substratum type and nitrogen dose (mean from the years 2005–2006)
Tabela 1. Plonowanie truskawki odmiany 'Honeoye' w zależności od rodzaju podłoża i dawki azotu (średnio z lat 2005– 2006)

Substrate Podłoże	Total yield (g·plant^{-1}) Plon ogólny (g·roślina^{-1})			Marketable yield (g·plant^{-1}) Plon handlowy (g·roślina^{-1})			Mean fruit weight (g) Średnia masa owocu (g)		
	nitrogen dose – dawka azotu								
	N_1	N_2	$\bar{x}$	N_1	N_2	$\bar{x}$	N_1	N_2	$\bar{x}$
Peat – Torf	524.7	579.5	552.1	368.4	404.9	386.6	12.4	13.2	12.8
Peat+bark – Torf + kora	492.7	560.9	526.8	340.5	417.2	378.8	12.2	13.2	12.7
Peat+sawdust – Torf+trociny	461.8	352.3	407.1	297.0	232.3	264.6	10.0	9.80	9.90
$\bar{x}$	493.1	497.6		335.3	351.5		11.5	12.1	
$LSD_{0.05}$ – $NIR_{0,05}$									
Substratum – Podłoże	114.8			94.7			1.57		
N dose – Dawka N	n.s. – ni.			n.s. – ni.			n.s. – ni.		

previous studies [Jarosz and Konopińska 2006, 2010], as well as with the reports of other authors, who demonstrated a high usability of pine bark as an independent substratum or in mixtures with peat in strawberry growing [Paranjpe et al. 2003, Simonin 2004]. Significantly lower total (407.1 g·plant^{-1}) and marketable yield of strawberry fruit (264.6 g·plant^{-1}) was reported when plants were grown in peat with pine sawdust, compared to the remaining examined substrata. Besides, strawberries growing in this substratum gave fruit of significantly lower unit weight (9.90 g). Lower total and marketable yield, as well as significantly smaller fruits of strawberry grown in peat with sawdust most probably should be justified by poorer supply of plants with nitrogen, caused by biological sorption of this component [Markiewicz et al. 2008]. The confirmation of this thesis is significantly lower total nitrogen contents in the plant leaves (2.43% d.m.) and in the rhisosphere of strawberry grown in this substratum (tab. 2, 3). Additionally, Dorais et al. [2007] also indicate the possibility of phytotoxic effect of certain sawdust components upon the plant, such as phenols and terpenes. This phenomenon might have also affected strawberry yielding in the presented studies. It is true that composting organic materials decreases the risk of phytotoxicity, but the effectiveness of this process to a substantial extent depends on the duration, as well as on the appropriate moistening and aeration [Hatten et al. 2005].

In the assessment irrespective of the kind of substratum, the general and marketable yield of strawberry fruit collected from plants fertilized with a lower nitrogen dose (140 mg·dm^{-3}), being, respectively: 493.1 g·plant^{-1} and 335.3 g·plant^{-1}, did not significantly differ from the general and marketable yield of fruit from plants fertilized with nitrogen in the dose of 210 mg·dm^{-3} (respectively: 497.6 g·plant^{-1} and 351.5 g·plant^{-1}). These results correspond with the studies by Lamarre and Lareau [1997], where no significant effect of increased nitrogen and potassium fertilization upon strawberry yield was found.

Table 2. Nutrients content (mg·dm^{-3}) in root zone of 'Honeoye' variety strawberries depending on the type of substratum and nitrogen dose (mean from the years 2005–2006 years) as compared to recommended contents [Breś at al. 2003]

Tabela 2. Zawartość składników pokarmowych (mg·dm^{-3}) w środowisku korzeniowym roślin truskawki odmiany 'Honeoye' w zależności od rodzaju podłoża i dawki azotu (średnio z lat 2005–2006) w porównaniu do wartości zalecanych [Breś i in. 2003]

Substrate Podłoże	$N-NH_4$		$N-NO_3$		$P-PO_4$		K		Ca		Mg	
	nitrogen dose – dawka azotu											
	N_1	N_2	N_1	N_2	N_1	N_2	N_1	N_2	N_1	N_2	N_1	N_2
Peat – Torf	25	29	172	284	176	188	353	239	1285	1210	166	125
Peat + bark – Torf + kora	35	57	154	265	191	193	368	210	1039	1052	124	139
Peat + sawdust – Torf + trociny	11	46	114	251	156	149	192	346	1250	1218	144	156
Recommended minimum Zalecane minimum	0		160		140		170		500		130	
Recommended maximum Zalecane maksimum	40		210		180		220		1500		170	

Table 3. Chemical composition of 'Honeoye' variety strawberry leaves (% d.m) depending on the type of substratum and nitrogen dose (mean from the years 2005–2006)

Tabela 3. Skład chemiczny liści truskawki odmiany 'Honeoye' (% s.m.) w zależności od rodzaju podłoża i dawki azotu (średnio z lat 2005–2006)

Substrate Podłoże	N Total N ogółem			P			K			Ca			Mg		
	nitrogen dose – dawka azotu														
	N_1	N_2	$\bar{x}$	N_1	N_2	$\bar{x}$	N_1	N_2	$\bar{x}$	N_1	N_2	$\bar{x}$	N_1	N_2	$\bar{x}$
Peat Torf	2.50	2.81	2.66	0.24	0.25	0.24	2.00	2.04	2.02	0.71	0.40	0.55	0.23	0.21	0.22
Peat + bark Torf + kora	2.46	2.80	2.63	0.28	0.27	0.28	1.94	1.85	1.89	0.74	0.48	0.61	0.26	0.24	0.25
Peat + sawdust Torf + trociny	2.34	2.52	2.43	0.21	0.23	0.22	2.13	2.05	2.09	0.67	0.55	0.61	0.23	0.24	0.24
$\bar{x}$	2.44	2.71		0.24	0.25		2.02	1.98		0.70	0.48		0.24	0.23	
$LSD_{0.05}$ – $NIR_{0,05}$															
Substrate – Podłoże	0.19			n.s. – ni.			n.s. – ni.			n.s. – ni.			n.s. – ni.		
N dose – Dawka N	0.26			n.s. – ni.			n.s. – ni.			0.12			n.s. – ni.		

The contents of examined macronutrients in plant leaves (tab. 3) is interesting, compared to their contents in the rhisosphere (tab. 2). In the leaves of strawberries fertilized with a higher nitrogen dose (210 mg·dm^{-3}) significantly more nitrogen total was found (2.71% d.m.), compared to the plants fertilized with this component in the amount of 140 mg·dm^{-3} (2.44% d.m.). However, this had no correlation with plant yielding. This is consistent with numerous reports, proving that increasing nitrogen fertilization does not significantly influence the increase of strawberry yield [Almaliotis et al. 2002, Jarosz and Konopińska 2006, 2010]. The analysis of obtained results did not demonstrate a significant differentiation in phosphorus and potassium contents in the leaves of strawberries grown in particular study objects (tab. 3). The reported contents of these nutrients, contained in the range from 0.21 to 0.28% P d.m. and 1.85–2.13% K d. m., should be regarded as optimum values [Almaliotis et al. 2002]. What is worth noticing, is the contents of calcium in strawberry leaves and fruit, depending on the examined factors. Despite high contents of this element in the rhisosphere of plants grown in particular objects (tab. 2), its contents in the leaves (0.48–0.74% d.m.), should be regarded as low [Almaliotis et al. 2002]. Besides, the statistical analysis of the obtained results demonstrated a significantly lower contents of calcium in the leaves and fruit of plants fertilized with nitrogen in the dose of 210 mg·dm^{-3} compared to strawberries fertilized with this component in the dose of 140 mg·dm^{-3}. These results are convergent with previous studies, where significantly less calcium was found in plants together with the increase of nitrogen doses [Jarosz and Konopińska 2010]. This dependence should be regarded as unfavorable, because the level of calcium in strawberry fruit to a substantial extent determines their firmness and durability [MacNaeidhe 2002].

The chemical composition of strawberry fruit depends mainly on cultivar, fruit maturity degree and climatic conditions in growing period. It is also determined by cultivation technology and manner of fertilization [Recamales et al. 2007]. The contents of dry matter, extract and macrocomponents (N, P, K, Ca, Mg), determined in fruit collected from particular objects (tab. 4–5) were comparable to the results quoted by other authors [Almaliotis et al. 2002, Michalski and Winiarska 2003, Nestby et al. 2004, Yavari et al. 2008]. This proves the correct nutrition and growth of strawberries cultivated in the presented studies. It should be emphasized that the contents of dry matter (10.6%), as well as of extract (5.93%) were significantly lower in plants fertilized with a higher dose of nitrogen (210 mg·dm^{-3}). Similar results were obtained in previous studies [Jarosz and Konopińska 2010]. Decreasing such significant parameters of assessing the use value of strawberry fruit, which are dry matter and extract contents reveals the necessity of moderate nitrogen fertilization of strawberries grown in organic substrata with the share of peat [Recamales et al. 2007]. The statistical analysis of nitrates (V) in fruit revealed a significant differentiation of this parameter, depending on the examined factors (tab. 4). The contents of nitrates in plants and their usable parts depends on many factors, the most important of which are: the contents of available nitrogen in rhisosphere, the form in which this element is taken up, as well as the activity of nitrate reductase [Taghavi et al. 2004]. According to Darnell and Stutte [2001] strawberry is a species preferring the nitrate form, although for better uptake of nitrogen the plants should also be provided with the ammonium form. Considering the contents of mineral nitrogen in the plant rhisosphere, depending on the examined factors (tab. 2), the demonstrated differentiation of nitrate (V) contents in fruit is understandable. It should be emphasized that the nitrate (V) contents in strawberry fruit reported in the studies (120–360 mg NO_3^-·kg f.w.) are substantially lower than the values given in literary sources [Taghavi et al. 2004]. The analysis of fruit chemical composition results revealed significantly more total nitrogen (1.58% d.m.) and potassium (2.08% d. m.) in the fruit of plants fertilized with a higher nitrogen dose (210 mg·dm^{-3}).

Table 4. Chemical composition of 'Honeoye' variety strawberry berries depending on the type of substratum and nitrogen dose (mean from the years 2005–2006)
Tabela 4. Skład chemiczny owoców truskawki odmiany 'Honeoye' w zależności od rodzaju podłoża i dawki azotu (średnio z lat 2005–2006)

Substrate Podłoże	Dry matter (%) Sucha masa (%)			Soluble solids (%) Ekstrakt (%)			Nitrates (mg $NO^-_3 \cdot kg^{-1}$ fr.w.) Azotany V (mg· $NO^-_3 \cdot kg^{-1}$ św.m.)		
	nitrogen dose – dawka azotu								
	N_1	N_2	$\bar{x}$	N_1	N_2	$\bar{x}$	N_1	N_2	$\bar{x}$
Peat – Torf	10.5	10.1	10.3	6.28	4.83	5.55	265.0	360.0	312.5
Peat+bark – Torf +kora	11.9	10.2	11.0	7.35	6.43	6.89	190.0	240.0	215.0
Peat+sawdust – Torf+trociny	11.9	11.3	11.6	6.92	6.55	6.74	120.0	295.0	207.5
$\bar{x}$	11.4	10.6		6.85	5.93		191.7	298.3	
$LSD_{0.05}$ – $NIR_{0,05}$									
Substrate – Podłoże		0.95			0.78			92.7	
N dose – Dawka N		0.78			0.52			79.3	

Table 5. Mineral content of 'Honeoye' variety strawberry berries (% d.m) depending on the type of substrate and nitrogen dose (mean from the years 2005–2006)
Tabela 5. Zawartość składników mineralnych w owocach truskawki odmiany 'Honeoye' (% s.m.) w zależności od rodzaju podłoża i dawki azotu (średnio z lat 2005–2006)

Substrate Podłoże	N Total N ogółem			P			K			Ca			Mg		
	nitrogen dose – dawka azotu														
	N_1	N_2	$\bar{x}$	N_1	N_2	$\bar{x}$	N_1	N_2	$\bar{x}$	N_1	N_2	$\bar{x}$	N_1	N_2	$\bar{x}$
Peat Torf	1.31	1.56	1.44	0.24	0.18	0.21	1.86	2.18	2.02	0.16	0.10	0.13	0.11	0.07	0.09
Peat + bark Torf + kora	1.40	1.63	1.51	0.25	0.20	0.22	1.82	2.05	1.93	0.16	0.10	0.13	0.07	0.08	0.08
Peat + sawdust Torf + trociny	1.42	1.56	1.49	0.27	0.26	0.27	2.04	2.01	2.02	0.14	0.11	0.12	0.08	0.07	0.07
$\bar{x}$	1.38	1.58		0.25	0.21		1.90	2.08		0.15	0.10		0.09	0.07	
$LSD_{0.05}$ – $NIR_{0,05}$															
Substrate – Podłoże		n.s. – ni.			n.s. – ni.			n.s. – ni.			n.s. – ni.			n.s. – ni.	
N dose – Dawka N		0.16			0.04			0.12			0.04			n.s. – ni.	

The presented results, as well as the previous studies [Jarosz and Konopińska 2006, 2010] confirm high usability of substratum consisting of peat and composted pine bark, mixed in volume ratio of 1 : 1 in strawberry growing. Using a substratum with the share of composted pine sawdust requires establishing different fertilization recommendations, compared to the traditional growing in peat. This concerns especially nitrogen [Ao et al. 2008, Jarosz and Konopińska 2010].

CONCLUSIONS

1. Total and marketable yields of 'Honeoye' strawberry fruits grown in peat and peat mixed with pine bark did not significantly differ.
2. Yielding of strawberries grown in peat mixed with composted pine sawdust was significantly worse compared to the remaining substrata.
3. The quantity of total and marketable yield, as well as the average strawberry fruit size did not depend on the differentiated nitrogen fertilization.
4. In the leaves of plants fertilized with a higher nitrogen dose, compared to the lower dose, significantly more total nitrogen and less calcium were demonstrated.
5. The strawberry plants fertilized with a higher nitrogen dose contained in their fruits significantly more nitrates (V), total nitrogen and potassium, but less dry matter, extract and calcium.

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PLONOWANIE I SKŁAD CHEMICZNY TRUSKAWKI ODMIANY 'HONEOYE' W ZALEŻNOŚCI OD RODZAJU PODŁOŻA I DAWKI AZOTU

Streszczenie. Uprawa truskawki pod osłonami w podłożach pozwala wyeliminować stosowanie kosztownego i szkodliwego dla środowiska odkażania gleby, a jednocześnie gwarantuje uzyskanie większego i lepszego jakościowo plonu w porównaniu z tradycyjnymi uprawami gruntowymi. W latach 2005–2006 przeprowadzono badania mające na celu określenie wpływu trzech rodzajów podłoża (torf, torf zmieszany z kompostowaną korą sosnową w proporcji 1 : 1, torf zmieszany z kompostowanymi trocinami sosnowymi w proporcji 1 : 1) oraz zróżnicowanej dawki azotu (140 lub 210 mg N·dm^{-3}) na plonowanie, skład chemiczny liści oraz owoców truskawki (*Fragaria* × *ananasa* Duch.) odmiany 'Honeoye' uprawianej w nieogrzewanym tunelu foliowym. Wielkość plonu ogólnego i handlowego owoców truskawki uprawianej w torfie oraz w torfie z korą sosnową nie różniła się istotnie. Mniejszy plon ogólny (407,1 g·roślina^{-1}) i handlowy (264,6 g·roślina^{-1}) owoców odnotowano przy uprawie roślin w torfie zmieszanym z trocinami sosnowymi. Rośliny uprawiane w torfie zmieszanym z trocinami wydały owoce o istotnie mniejszej masie jednostkowej w porównaniu z roślinami rosnącymi w pozostałych podłożach. W badaniach nie wykazano istotnego wpływu zróżnicowanego nawożenia azotem na plonowanie truskawki. W liściach roślin nawożonych azotem w dawce 200 mg N·dm^{-3} stwierdzono istotnie więcej azotu oraz mniej wapnia w porównaniu z roślinami nawożonymi mniejszą dawką tego składnika. W owocach truskawki nawożonej większą dawką azotu odnotowano istotnie więcej azotanów (V), azotu ogółem i potasu oraz mniej suchej masy, ekstraktu i wapnia w porównaniu z owocami zebranymi z roślin nawożonych azotem w dawce 140 mg N·dm^{-3}.

Słowa kluczowe: uprawa bezglebowa, podłoża organiczne, nawożenie azotem, skład chemiczny roślin

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