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EFFECT OF SUBSTRATE TYPE AND NITROGEN FERTILIZATION UPON YIELDING AND CHEMICAL COMPOSITION OF „ELSANTA" STRAWBERRY CULTIVAR GROWN IN UNHEATED FOIL TUNNEL

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Abstract. The main factors determining the quantity and quality of the yield of plants grown in the soilless system is the kind of cultivation substrate used and the level of supplying the plants with nutrients. Studies conducted in the years 2005–2006 were aimed at determining the effect of substrates (peat, peat mixed with pine bark in the proportion of 1:1, peat with pine sawdust in the ratio of 1:1), as well as of differentiated nitrogen dose (140 and 210 mg $N\cdot dm^{-3}$) upon yielding, chemical composition of strawberry (*Fragaria* × *ananasa* Duch.) leaves and fruit, cultivar 'Elsanta', grown in unheated foil tunnel. In those studies no significant differences were found in total and marketable yield of strawberry fruit grown in peat, as well as in peat with pine bark. Significantly smaller total (435.8 $g\cdot plant^{-1}$) and marketable (286.5 $g\cdot plant^{-1}$) fruit yield was reported when strawberries were grown in peat mixed with pine sawdust. In plants grown in peat mixed with sawdust significantly smaller fruit unit weight (10.7 g) was found, as compared to plants that grew in the remaining substratums. In our studies no significant effect of differentiated nitrogen fertilization upon strawberry yielding was demonstrated. In the leaves of strawberries fertilized with nitrogen in the dose of 210 mg $N\cdot dm^{-3}$ we found significantly more nitrogen and phosphorus, as well as less calcium and magnesium, as compared to plants fertilized with smaller doses of this nutrient. The fruit of strawberries fertilized with a higher nitrogen dose contained significantly more nitrogen and potassium, as well as less vitamin C and soluble solids, as compared to the fruit collected from plants fertilized with nitrogen in the dose of 140 mg $N\cdot dm^{-3}$.

Key words: soilless cultivation, peat, peat with bark, peat with sawdust, nitrogen dose, fruit yield, chemical composition

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INTRODUCTION

The soilless plant-growing system, using substrates, allows for eliminating the application of soil decontamination, which is costly and noxious for the environment [Recamales et al. 2007]. Simultaneously, cultivation in the soilless system guarantees obtaining greater and better quality yield, as compared to the traditional plant growing in the soil [Lopez-Medina et al. 2004]. The most popular substratum applied in soilless strawberry growing under covers is peat, mainly because of its very good cultivation properties [Kemppainen et al. 2004, Lieten et al. 2004]. High economic and ecological costs, related to the use of this substrate, make us seek solutions enabling us to limit the application of peat. Such possibilities can be obtained by mixing peat with easily available and cheaper materials, such as bark and sawdust [Rumpel 1998, Lieten et al. 2004]. Many authors emphasize that the barrier that significantly restricts broader application of mixed substrates is lack of detailed fertilization instructions [Benton 1999, Pudelski 1996]. Numerous studies indicate that the key factor determining the yield quantity and quality of strawberries grown in the soilless system, is appropriate nitrogen fertilization [Nestby et al. 2004, Jarosz and Konopińska 2006].

The undertaken studies were aimed at determining the influence of substrates (peat, peat with pine bark, mixed in the ratio of 1:1, peat with pine sawdust, mixed in 1:1 ratio) and of the differentiated nitrogen fertilization (140 or 210 mg N·dm^{-3}) upon yielding and chemical composition of 'Elsanta' strawberry variety leaves and fruit.

MATERIAL AND METHODS

Studies with strawberries (*Fragaria* × *ananassa* Duch) of 'Elsanta' variety were conducted in unheated foil tunnel in the years 2005–2006. The plants were grown in containers of the capacity of 5 dm^3 in ten replications. A replication was a container with one plant. The experiment was established in complete randomization system. In our studies we used green strawberry seedlings of A+ size, which were planted on the 7th September 2004 and on the 2nd September 2005. The substrates were formed by transitory peat, peat mixed with composted pine bark, in volume ratio of 1:1, and peat mixed with composted pine sawdust in volume ratio of 1:1. The substratum reactions were regulated before planting, and during the studies it was maintained on the level of pH 5,5–6,0. Additionally, in our studies the level of nitrogen fertilization was differentiated by supplying this nutrient to plants in the doses of: N_1 – 140 mg·dm^{-3} or N_2 – 210 mg mg·dm^{-3}. The amount of the remaining nutrients was equal for all the plants and it was (mg·dm^{-3}): 140 P, 250 K, 100 Mg. Micronutrients were applied in amounts recommended for peat substrate [Pudelski 1998]. Nutrients were supplied to plants in the form of water solutions of fertilizers, every two weeks. Due to high contents of calcium in water used for watering the plants (140–160 mg·dm^{-3}) no additional fertilization with this nutrient was applied. The plants were watered with the use of droplet method, using Galcon time driver, with daily water outflow of 150–250 ml for one plant. Strawberry flowers were pollinated by bumblebee (*Bombus terrestris*). Plant protection procedures were conducted in accordance with recommendations. The experiments were finished after the end of fruit collection (23rd June 2005 and 22nd June 2006).

Fruit harvesting, lasting from 16th May to 21st June 2005 and from 19th May to 21st June 2006 was performed every two days. The fruits were counted and weighed, determining total and marketable yield, as well as mean weight of one fruit (PN-R-75535:1996)

The substrate analysis was performed before establishing the experiment and in vegetation season, every four weeks. Determinations of $N-NH_4$, $N-NO_3$, $P-PO_4$, K, Ca, Mg contents were performed after extracting a sample of substrate (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 vanadomolibdate, potassium, calcium and magnesium – using ASA method (Perkin-Elmer Analyst 300).

Leaves for the analyses were sampled from plants in full blossoming and in the middle of fructification. 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 furnace (temp. 550ºC) phosphorus, potassium, calcium and magnesium – using the same methods as in substrate analysis.

Fruits for the analysis were sampled in the phase of harvesting ripeness, in the middle of fructification. In the fresh material dry matter was determined with the use of dryer method, soluble solids – refractometrically, vitamin C – with the use of test bands (RQ-Flex, Merck). Having dried the material, we determined the total nitrogen (using Kjeldahl's method), phosphorus, potassium and calcium – using the same methods as in leaf analysis.

The statistical elaboration of results was conducted with the use of variance analysis method, on mean values, using Tukey's test for assessing differences, with significance level $\alpha = 0,05$. The presented results are mean values from two study years.

RESULTS AND DISCUSSION

Numerous studies prove that the main factors determining the quantity and quality of the yield of plants grown in the soilless system, is the kind of cultivation substrate used and the level of supplying the plants with nutrients [Jarosz and Konopińska 2006, Nestby et al. 2004]. The application of substrates which are alternatives for peat, with definitely different physical and chemical properties, requires more specific recommendations for fertilization, especially as far as nitrogen is concerned [Pudelski 1996, Markiewicz et al. 2008].

The statistical analysis of results obtained in the performed studies did not demonstrate any significant differences in total and marketable yield of strawberry fruit grown in peat and peat mixed with pine bark (tab. 1). The obtained results are consistent with the previous studies [Jarosz and Konopińska 2006], as well as with the reports of other authors, who demonstrated that pine bark was quite useful as a self-contained substrate, or in mixtures with peat, in soilless strawberry growing [Paranjpe et al. 2003, Simonin 2004]. Lisiecka [1998] in turn, growing strawberries in the substrate of pine bark mixed with low peat, obtained a significantly lower fruit yield, as compared to peat substrate. The analysis of results obtained in the conducted studies revealed a significantly lower total (435.8 g·plant^{-1}) and marketable yield (28.5 g·plant^{-1}) of strawberry fruit growing in peat with pine sawdust, as compared to the remaining studied substratums. The reason for poorer yield of strawberry grown in peat with sawdust was most probably worse supply of plants with nitrogen caused by the biological sorption of this nutrient [Markiewicz et al. 2008]. This thesis is confirmed by significantly lower contents of total nitrogen in plant leaves (2.09% d.m.) and in the root zone of strawberry grown in this substratum (fig. 1). Dorais et al. [2007] also emphasize the possibility of phyto-toxic effect of certain components of sawdust during plant growing in this material. This phenomenon might also have influenced strawberry yielding in the presented studies. It is true that composting organic materials decreases the risk of phyto-toxicity towards cultivable plants, but the effectiveness of this process to a large extent depends upon maintaining appropriate physico-chemical parameters [Hatten et al. 2005].

Table 1. Effect of substrate type and nitrogen fertilization on the strawberry yielding
Tabela 1. Wpływ rodzaju podłoża oraz nawożenia azotem na plonowanie truskawki

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 Średnia masa owocu g		
	nitrogen fertilization – nawożenie azotem								
	N_1	N_2	$\bar{x}$	N_1	N_2	$\bar{x}$	N_1	N_2	$\bar{x}$
Peat Torf	653.7	619.1	636.4	495.8	468.3	482.1	16.2	18.3	17.3
Peat + bark Torf + kora	646.3	587.9	617.1	459.2	425.1	442.2	15.7	16.5	16.1
Peat + sawdust Torf + trociny	436.5	435.1	435.8	290.8	282.1	286.5	11.1	10.4	10.7
$\bar{x}$	578.8	547.4		415.3	391.8		14.3	15.1	
$LSD_{0.05}$ $NIR_{0,05}$ substrate – podłoże N dose – dawka N	 83,6 n.s. – ni.			 65.5 n.s. – ni.			 2.19 n.s. – ni.		

In the assessment irrespective of the kind of substrate, total and marketable yield of strawberry fruits collected from plants fertilized with lower dose of nitrogen (140 mg·dm^{-3}), equaling, respectively, 578.8 g·plant^{-1} and 415.3 g·plant^{-1}, did not significantly differ from the total and marketable yield of the fruit from plants fertilized with nitrogen in the dose of 210 mg·dm^{-3} (respectively: 547.4 g·plant^{-1} and 391.8 g·plant^{-1}). These results correspond to the studies by Lamarre and Lareau [1997], who demonstrated lack of significant effect of increased fertilization with nitrogen and potassium upon strawberry yield.

The contents of the studied macronutrients in the plant leaves (tab. 2) seem to be interesting as compared to their contents in the rhisosphere (fig. 1). In the leaves of strawberries fertilized with a higher nitrogen dose (210 mg·dm^{-3}) significantly more total nitrogen was reported (2.44% d.m.), as compared to plants fertilized with this nutrient in the amount of 140 mg·dm^{-3} (2.27% d.m.), however, this did not affect plant yielding. It is consistent with numerous reports proving that increasing nitrogen dose does not significantly influence the increase of strawberry yield [Almaliotis et al. 2002, Jarosz and Konopińska 2006].

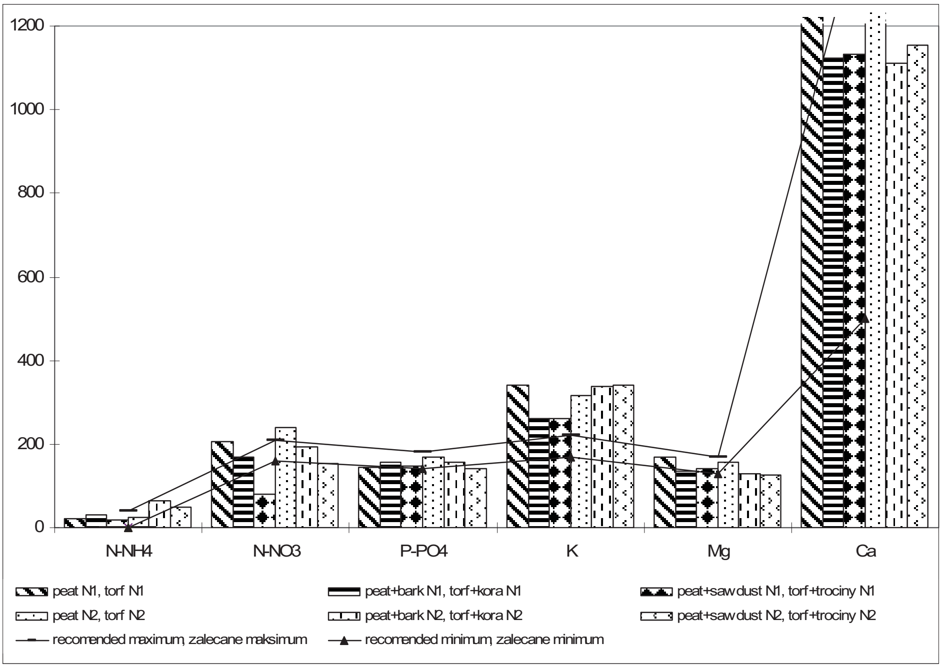

Fig. 1. Nutrients contents (mg·dm^{-3}) in root zone depending on the type of substrate and nitrogen fertilization as compared to recommended contents [Breś at al. 2003]

Ryc. 1. Zawartość składników pokarmowych (mg·dm^{-3}) w środowisku korzeniowym roślin w zależności od rodzaju podłoża i nawożenia azotem w porównaniu z wartościami zalecanymi [Breś i in. 2003]

The statistical analysis of the results demonstrated a significantly higher contents of phosphorus (0.48% d.m.) in the leaves of plants fertilized with a higher nitrogen dose (210 mg·dm^{-3}). No significant differences were found in the contents of this nutrient in the leaves, depending on the kind of the applied substrate.

The contents of potassium in the leaves of examined plants did not significantly differ in particular study objects and was contained in the interval 1.90–2.09% d.m., which, according to Almaliotis et al. [2002] should be regarded as optimal values. It should be emphasized that in the rhisosphere the potassium contents was higher than it had been recommended (fig. 1). The phenomenon of increased nutrient concentration, compared to the amounts supplied to plants, is characteristic of growing in organic substrates [Yavari et al. 2008]. In spite of high contents of calcium in the rhisospheres of plants grown in the particular objects (fig. 1) the contents of this nutrient in leaves (0.53–0.91% d.m.) should be regarded as low [Almaliotis et al. 2002].

Table 2. Effect of the substrate type and nitrogen fertilization on the contents of selected nutrients in strawberry leaves (% d.m)
Tabela 2. Wpływ rodzaju podłoża oraz nawożenia azotem na zawartość wybranych składników w liściach truskawki (% s.m.)

Substrate Podłoże	N total N ogółem			P			K			Ca			Mg		
	nitrogen fertilization – nawożenie azotem														
	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	2.54	2.62	2.58	0.42	0.49	0.45	1.97	2.09	2.03	0.91	0.53	0.72	0.18	0.16	0.17
Peat + bark Torf + kora	2.29	2.52	2.41	0.45	0.53	0.49	2.02	1.95	1.98	0.88	0.68	0.78	0.21	0.15	0.18
Peat + sawdust Torf + trociny	1.98	2.20	2.09	0.41	0.44	0.43	1.90	2.03	1.96	0.73	0.73	0.73	0.16	0.16	0.16
$\bar{x}$	2.27	2.44		0.43	0.48		1.96	2.02		0.84	0.64		0.18	0.15	
$LSD_{0.05}$ $NIR_{0,05}$															
substrate – podłoże		0.31			n.s. – ni.			n.s. – ni.			n.s. – ni.			n.s. – ni.	
N dose – dawka N		0.16			0.05			n.s. – ni.			0.16			0.02	

A similar dependence was demonstrated in the case of magnesium. The contents of this nutrient in the rhisosphere were maintained on the level recommended for the organic substratums (fig. 1). In the strawberry leaves the reported magnesium contents ranged from 0.15 to 0.21% d.m, which should be regarded as deficit values [Almaliotis et al. 2002, Michalski and Wieniarska 2003]. This is an indication of the necessity of increasing magnesium concentration in the strawberry rhisosphere above the recommended amounts, especially in the case of high potassium and magnesium contents.

The chemical composition of strawberry fruit depends mainly on the variety, degree of fruit maturity, and climatic conditions during growing, but it is also determined by cultivation technology and manner of fertilization [Recamales et al. 2008]. The contents of dry matter, vitamin C, soluble solids and macronutrients (N P, K, Ca, Mg) demonstrated in fruits collected from particular study objects (tab. 3) are comparable to the results quoted by other authors [Almaliotis et al. 2002, Michalski and Wieniarska 2003, Nestby et al. 2004, Yavari et al. 2008]. This confirms the proper development of strawberries grown in the presented studies. It is noteworthy that the contents of soluble solids (5.58%) and vitamin C (55.8 mg·100 g^{-1} f.w.) is significantly lower in fruits coming from plants fertilized with a higher nitrogen dose (210 mg·dm^{-3}). These are significant parameters in assessing the use value of strawberry fruit, as to a significant extent they determine its taste value [Recamales et al. 2008]. The result analysis of the fruit chemical composition demonstrated significantly more total nitrogen (1.85% d.m.) and potassium (2.10% d. m.) in the fruit of plants fertilized with a higher dose of nitrogen (210 mg·dm^{-3}).

Table 3. Effect of substrate type and nitrogen fertilization on the chemical composition of strawberry berries
Tabela 3. Wpływ rodzaju podłoża oraz nawożenia azotem na skład chemiczny owoców truskawki

Substrate Podłoże	Dry matter Sucha masa %			Soluble solids Ekstrakt (%)			Vitamin C $mg \cdot 100g^{-1}$fr.w. Witamina C $mg \cdot 100g^{-1}$św.m.			N Total % d.w. N ogółem % s.m.			P % d.w. % s.m.			K % d.w. % s.m.			Ca % d.w. % s.m.			Mg % d.w. % s.m.		
	nitrogen fertilization – nawożenie azotem																							
	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	$\bar{x}$	N_1	N_2	$\bar{x}$	N_1	N_2	$\bar{x}$	N_1	N_2	$\bar{x}$
Peat Torf	10.17	9.22	9.70	6.20	5.47	5.83	69.5	53.5	61.5	1.61	1.99	1.80	0.29	0.32	0.31	1.86	2.16	2.01	0.12	0.12	0.12	0.09	0.08	0.08
Peat + bark Torf + kora	10.14	9.75	9..95	7.17	5.23	6.20	70.5	61.0	65.8	1.60	2.07	1.84	0.33	0.35	0.34	1.94	2.03	2.03	0.15	0.12	0.13	0.09	0.07	0.08
Peat + sawdust Torf + trociny	9.02	9.77	9.40	7.00	6.03	6.52	66.0	53.0	59.5	1.39	1.47	1.43	0.29	0.36	0.33	1.97	2.12	2.00	0.19	0.14	0.17	0.08	0.08	0.08
$\bar{x}$	9.78	9.58		6.79	5.58		68.7	55.8		1.53	1.85		0.30	0.34		1.92	2.10		0.15	0.13		0.09	0.08	
$LSD_{0,05}$ $NIR_{0,05}$																								
substrate – podłoże	n.s. – ni.			n.s. – ni.			n.s. – ni.			n.s. – ni.			n.s. – ni.			n.s. – ni.			n.s. – ni.			n.s. – ni.		
N dose – dawka N	n.s. – ni.			0.62			8.2			0.30			n.s. – ni.			0.07			n.s. – ni.			n.s. – ni.		

The presented results confirm high usefulness of substrate consisting of peat and pine bark (1:1) in the soilless growing of strawberry under covers. Using substratum with composted pine sawdust requires establishing different fertilizing recommendations, especially as far as nitrogen is concerned [Ao et al. 2008]. Certain authors also point to the necessity of preparing new methods of assessing the abundance of rhizosphere in growing plants in organic substratums with differentiated physico-chemical properties [Ao et al. 2008, Babik 2006].

CONCLUSIONS

1. No significant differences were found in total and marketable yield of strawberry fruits grown in peat and peat with pine bark.
2. Plants grown in peat with pine sawdust gave lower yield, as compared to the remaining substrates.
3. No significant differences were demonstrated in the quantity of total and marketable yield, as well as in mean size of strawberry fruits, depending on the level of nitrogen fertilization.
4. In the leaves of plants fertilized with nitrogen in the dose of 210 mg $N \cdot dm^{-3}$ significantly more nitrogen and phosphorus was found, and less calcium and magnesium.
5. Strawberry fruits fertilized with a higher dose of nitrogen contained significantly more nitrogen and potassium, and less vitamin C and soluble solids.

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WPŁYW RODZAJU PODŁOŻA I NAWOŻENIA AZOTEM NA PLONOWANIE I SKŁAD CHEMICZNY TRUSKAWKI ODMIANY 'ELSANTA' UPRAWIANEJ W NIEOGRZEWANYM TUNELU FOLIOWYM

Streszczenie. Głównymi czynnikami decydującymi o ilości i jakości plonu roślin w uprawach bezglebowych jest rodzaj podłoża uprawowego oraz poziom zaopatrzenia w składniki pokarmowe. Badania przeprowadzone w latach 2005–2006 miały na celu określenie wpływu podłoży (torf , torf zmieszany z korą sosnową w proporcji 1:1, torf z trocinami sosnowymi w proporcji 1:1) oraz zróżnicowanej dawki azotu (140 i 210 mg N·dm^{-3}) na plonowanie, skład chemiczny liści oraz owoców truskawki (*Fragaria* × *ananasa* Duch.) odmiany 'Elsanta' uprawianej w nieogrzewanym tunelu foliowym. W badaniach nie stwierdzono istotnych różnic w plonie ogólnym i handlowym owoców truskawki uprawianej w torfie oraz w torfie z korą sosnową. Istotnie mniejszy plon ogólny

(435,8 g·roślina^{-1}) i handlowy (286,5 g·roślina^{-1}) owoców odnotowano przy uprawie truskawki w torfie zmieszanym z trocinami sosnowymi. U roślin uprawianych w torfie zmieszanym z trocinami stwierdzono istotnie mniejszą masę jednostkową owoców (10,7 g) w porównaniu do roślin rosnących w pozostałych podłożach. W badaniach nie wykazano istotnego wpływu zróżnicowanego nawożenia azotem na plonowanie truskawki. W liściach truskawki nawożonych azotem w dawce 210 mg N·dm^{-3} stwierdzono istotnie więcej azotu i fosforu oraz mniej wapnia i magnezu w porównaniu z roślinami nawożonymi mniejszą dawką tego składnika. Owoce truskawki nawożonej większą dawką azotu zawierały istotnie więcej azotu i potasu oraz mniej witaminy C i ekstraktu w porównaniu do owoców zebranych z roślin nawożonych azotem w dawce 140 mg N·dm^{-3}.

Słowa kluczowe: uprawa bezglebowa, torf, torf z korą, torf z trocinami, dawka azotu, plon owoców, skład chemiczny

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