Influence of fertilization application and growing substrate on container-grown woody ornamentals

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ABSTRACT

Five fertilization systems and seven types of growing substrates were tested with two woody plant species with different nutritional demands (*Thuja occidentalis*, *Pyracantha coccinea*) grown in two-litre containers. The experiment was repeated in two vegetative seasons. Application of controlled release fertilizer (CRF) was proved the most reliable; it gave good or at least average results in dependence on used growing substrates. Significant differences between application of CRF and other fertilization systems were with *Pyracantha* plants. System using slow release fertilizer with additional nitrogen fertilizing also showed good results. Systems based only on liquid feeding were less reliable, with some substrates they showed very good results; with others (peat substrate, peat bark substrates with wood components) they were bad. Similar results were achieved with top dressing of granulated fertilizer. Evaluating the substrates good results were obtained by using mixtures of peat with components with higher content of nutrients – peat bark substrates, peat bark substrates with compost and non-peat mixtures of composted bark, wood fibres and compost. Significant differences between these types of substrates and peat one or peat bark substrate with wood components were both with *Thuja* plants and especially with *Pyracantha* plants, which have higher demand for nutrients. The experiments showed that peat based substrates amended with alternative components or non-peat substrates can bring better results than the peat ones.

Keywords: organic substrates; peat; alternative components; fertilization systems; growth response; *Thuja occidentalis*; *Pyracantha coccinea*

Fertilization systems of container-grown woody plants should be adapted to the type of growing substrate. Besides standard peat substrates, peat media amended with alternative components or non-peat ones are used. Developing peat alternative substrates is necessary for three reasons: the resources of peat are limited, the pressure for using waste from human or industrial activities increases rapidly and the economic necessity to use locally produced waste products (Guérin et al. 2001). The growing substrates should have stable physical and chemical properties during cultivation. Especially substrates with woody components, but also young peat have worse stability and ability to keep adequate air space (Prasad and O'Shea 1999). Using alternative components with low level of decomposition (wood fibres, bark) there is risk of nitrogen tie-up (Dubský and Šrámek 1998, Siegler 1998). On the other hand, alternative substrates with good decomposed components (Guérin et al. 2001) can show better performance than those using peat.

In the nursery practise, fertilization systems using CRF and SRF are widely used. Standard CRF used in various experiments is Osmocote. Application of Osmocote produced better results than standard systems with soluble preplant fertilizers and liquid feeding (Remešová and Přidalová 1997) and similar or better results than other types of CRF (Maher 1996, Sturm and Mac Cárthaigh 1997).

Two experiments were conducted to find out the effects of fertilization systems on container-grown woody ornamentals cultivated in various types of growing substrates. Fertilizers and fertilization systems were selected from those used in the nurseries in the Czech Republic. Evaluation of growing substrates was aimed at composition, physical properties and content of available nutrients.

MATERIAL AND METHODS

In two experiments (Table 1) with two species of woody plants (*Thuja occidentalis* L. cv. Smaragd a *Pyracantha coccinea* M. Roem cv. Red Column) five fertilization systems (Table 3) with seven types of growing substrates were tested (Table 2), altogether 35 variants. The experiment was repeated in two vegetative periods (1999, 2000). In the experiment (Table 2), common types of substrates were used (peat substrate – A and peat bark substrates – B, C, E) and substrates with higher content of alternative components (C*, D*, F, G). As alternative components there were used several types of composted bark (1999 – 2 types, 2000 – 4 types), wood fibres – Toresa and Cultifibre, sawdust and compost (composted grass, leaves and woody chips). All substrates were prepared on the production line with a sorter (diameter of the sieve 20 mm) by commercial firms producing growing substrates from

Table 1. Experiment design (1999, 2000)

Plants	*Thuja occidentalis* L. cv. Smaragd (0/1/1)
	Pyracantha coccinea M. Roem. cv. Red Column (0/2/0)
Potting	25. 4.–27. 4.
Density of plants	45 plants.m^{-2}
Containers	height 13 cm, volume 2 l
Irrigation	sprinkler irrigation
No. of variants	35 (7 substrates × 5 fertilization systems)
No. of replications	5
No. of plants in each replicate	10
Running evaluation	28. 6. (*Thuja*)
Final evaluation	19. 9.–20. 9.

their own components. Preplant fertilizers were applied immediately before planting. In both years the same types of substrates with similar properties were tested, more substrates (C*, D*) with alternative components were included in the experiment in 2000.

The tested fertilization systems (Table 3) represent the most used ones in nurseries in the Czech Republic. Preplant fertilization was combined with liquid feeding (system P, C, N) or with top dressing of granulated fertilizer Hydrokomplex (H). System S was based on slow release fertilizer (SRF) Silvamix forte combined with soluble fertilizers. Controlled release fertilizer (CRF) Osmocote (system O) was used without supplementary fertilizing. Fertilization systems P, H, S, O were identical in both experiments. Systems C (1999) and N (2000) differed in preplant fertilizers and liquid feeding.

Comparing applied rates of nutrients in fertilization systems (Table 3) the most nutrients were added in system S. This high rate of nutrients was caused by using SRF (granulated fertilizer contained ureaform and sparingly soluble potassium-magnesium phosphates) whose dissolving process takes two years. According to the experience with this type of fertilizer (unpublished experiments), the SRF was combined with soluble preplant fertilizer and supplementary nitrogen liquid feeding. Higher dose of nutrients was also applied in system H with top dressing. In systems P, C, N there was applied, in spite of intensive postplant fertilization, smaller amount of nutrients than by using CRF (system O).

Chemical analyses of dry samples (components, substrates) were carried out in accordance with the methods of investigation of horticultural soils and substrates (Soukup et al. 1987). Electric conductivity and pH value were estimated in water extract 1:10 (w:v), content of available nutrients was estimated in Göhler extract solution (0.52M CH_3COOH, 0.05M CH_3COONa) 1:10 (w:v). Chemical properties were determined at the beginning of the experiments with substrates without fertilizers and two weeks after application of soluble preplant fertilizers (systems P, C, N and H). Substrates in systems P, C and N were estimated in the second part of the vegetative period (4 August).

Physical properties of the substrates were determined (Valla et al. 1980, Šrámek and Dubský 1996) in cylinders with the volume of 100 cm^3 at the beginning of experiments.

With *Thuja* plants there were evaluated increments at the half and at the end of the vegetative period. With *Pyracantha* plants shoot length and fresh weight at the end of the experiments were measured. All data sets

Table 2. Types and composition of growing substrates

	Substrate: composition (% vol.)	Limestone (g.l^{-1})
A	peat substrate: 70% white peat + 30% black peat	5
B	peat bark substrate: 50% bark + 50% peat (white:black = 1:1)	4
C	peat bark substrate: 30% bark + 70% peat (white:black = 1:1)	4
C*	50% white peat + 20% bark + 30% Cultifibre	4
D	peat bark substrate with 10% clay: 50% bark + 40% peat (white:black = 1:1)	4
D*	50% white peat + 20% bark + 15% sawdust + 15% Cultifibre	4
E	bark peat substrate: 70% bark + 30% peat (white:black = 1:1)	4
F	30% Toresa + 50% bark + 20% compost	–
G	30% compost + 20% bark + 50% peat (white:black = 1:1)	2

* changed composition in 2000

Table 3. Fertilization systems and their design, applied rate of nutrients

Var.	Fertilizer	Content of nutrients (%) $N/P_2O_5/K_2O$	Rate ($g.l^{-1}$) concentration (%)	No.	Rate of nutrients ($mg.l^{-1}$ substrate) N	P	K
P	PG MIX	14/16/18	1 $g.l^{-1}$		140	70	149
	Kristalon Blue	19/6/20	0.2%	7*	199	28	196
	Kristalon White	15/5/30	0.2%	4*	91	13	149
	total rate				430	111	493
C	Cererit	10/9/14	3 $g.l^{-1}$		300	119	349
	Kristalon Blue	19/6/20	0.2%	7*	199	28	196
	Kristalon White	15/5/30	0.2%	3*	68	10	112
					567	156	657
N	PG MIX	14/16/18	1 $g.l^{-1}$		140	70	149
	DAM 390	30/–/–	0.2%	6*	350	0	0
	PK	–/20/24	0.2%	2*	0	39	90
	CK	–/–/26	0.2%	3*	0	0	135
	total rate				490	109	284
H	Hydrokomplex	12/11/18	2 $g.l^{-1}$		240	97	299
	Hydrokomplex	12/11/18	2 $g.l^{-1}$	2**	480	194	598
	total rate				720	291	897
S	Silvamix Forte	17.5/17.5/10.5	5 $g.l^{-1}$		875	385	436
	PG MIX	14/16/18	1 $g.l^{-1}$		140	70	149
	DAM 390	30/–/–	0.2%	3*	175	0	0
	total rate				1190	455	585
O	Osmocote 5–6	15/10/12	4 $g.l^{-1}$		600	176	398

preplant fertilizers – rate: $g.l^{-1}$ of substrate; No. – number of supplementary fertilizings
* liquid feeding – concentration: %, one application – 75 $ml.l^{-1}$ of substrate
soluble fertilizers – dosing: 2 $g.l^{-1}$ of solution – Kristalon Blue until 26. 7., Kristalon White until 25. 8.
liquid fertilizers – dosing: 2 $ml.l^{-1}$ of solution, contain of nutrients: $g.l^{-1}$ of fertilizer: DAM 390 g N, PK 300 g P_2O_5, 360 g K_2O, CK 360 g K_2O
** top dressing – rate: g per litre of substrate (15. 6. and 26. 7. 1999, 15. 6. and 14. 7. 2000)

were tested for normality and analysed by one-way and two-way (influence of the factors: fertilization system, type of substrate) analysis of variance. The significance level $p < 0.05$ was used, the significant differences between means were evaluated by Duncan's Multiple Range Test.

RESULTS AND DISCUSSION

Experiment 1999

Among the growing media, there were differences in physical properties according to their composition (Ta-

Table 4. Physical properties of growing substrates (experiment 1999)

Substrate	BD ($g.l^{-1}$)	TP	WPC	AS	P_C (% vol.)	P_S	P_N
A	140	90.4	68.7	21.7	50.6	24.7	15.2
B	230	85.1	60.0	25.1	42.6	26.0	16.5
C	210	86.5	62.6	23.9	44.7	24.4	17.4
D	350	80.6	59.6	21.0	45.9	19.3	15.4
E	330	81.4	56.2	25.3	39.3	25.4	16.8
F	230	85.7	58.6	27.1	36.6	32.1	16.9
G	300	82.3	54.4	27.9	40.9	21.2	20.3
Optimum	150–400	80–90	50–65	20–30	40–50	15–25	10–20

BD – bulk density, TP – total porosity, WPC – water pore capacity, AS – air space, P_C – capillary pore space, P_S – semicapillary pore space, P_N – noncapillary pore space, optimum for growing substrate

Table 5. pH value, electric conductivity (EC) and content of available nutrients in components (experiment 1999)

Component/ used in substrate	BD ($g.l^{-1}$)	pH	EC ($mS.cm^{-1}$)	$N\text{-}NH_4$	$N\text{-}NO_3$	P	K	Ca
				($mg.l^{-1}$ substrate)				
White peat/A–E, G	90	3.3	0.2	10	12	3	14	70
Black peat/A–E, G	190	3.6	0.26	23	25	4	20	380
Bark I/B–D, F–G	230	5.3	0.29	32	5	20	863	620
Bark II/E	350	5.9	0.39	105	7	210	910	920
Compost/F, G	430	7.4	0.66	103	103	229	1606	5710
Toresa/F	90	5.2	0.49	32	4	17	63	240

BD – bulk density

ble 4). The peat substrate A had the lowest bulk density (BD) and the higher water pore capacity (WPC). Similar properties were determined in peat bark substrates B, C and substrate F with wood fibres Toresa. Good physical properties of this non-peat substrate were influenced by combination of wood fibres with compost. Higher BD connected with lower porosity and WPC had substrate D with clay and substrate E with high part of composted bark II. Substrate G with high part of compost had similar properties. All tested substrates showed suitable physical properties.

When evaluating chemical properties and bulk density of the components (Table 5) there were differences among used types of peat and composted bark. Black peat had in comparison with white peat higher BD and higher content of available Ca. Bark II had in comparison with bark I higher BD and higher content of available nutrients, especially N and P. High content of nutrients was established in the compost.

Chemical analyses of substrates without preplant fertilization, only with pH correction by limestone (Table 6) showed how the components influenced the content of available nutrients. Substrates with higher part of composted bark B, E and compost F, G had high content of K. Substrates with compost and bark II had high content of P and N, especially $N\text{-}NH_4$.

The influence of components and the rates of limestone (Table 2) is evident in pH values and the content of available Ca (Table 6). Substrates A–D had pH about 5.5 and the content of Ca on the low level of optimum. Substrates F, G and E had pH about 6.5 and the content of Ca on the upper level of optimum.

After application of soluble fertilizers (systems P, C and H) EC and content of available nutrients increased. The highest increase was in system C after application of 3 g Cererit per l of substrate, the lowest in system P after application of 1 g PG MIX per l of substrate. EC and content of available nutrients were as follows: system C: 1–2 $mS.cm^{-1}$, 450–600 mg $N.l^{-1}$, 90–200 mg $P.l^{-1}$, 320–1100 mg $K.l^{-1}$, system H: 0.6–1.8 $mS.cm^{-1}$, 100–340 mg $N.l^{-1}$, 60–320 mg $P.l^{-1}$, 300–1000 mg $K.l^{-1}$ and system P: 0.4–0.9 $mS.cm^{-1}$, 60–300 mg $N.l^{-1}$, 45–190 mg $P.l^{-1}$, 150–1000 mg $K.l^{-1}$. The lower values were estimated in substrate D (content of N and P), and A (content of K), higher values were estimated in substrates E and F. The content of K was in all substrates (except E, F and A – system P) in the range of 300–500 $mg.l^{-1}$. In substrates E, F the content of K was extremely high (700–1000 $mg.l^{-1}$). After application of fertilizers media pH lowered by 0.2–0.8, the greatest fall from 7.1 to 6.3 was in substrate E, system H.

In the second half of vegetation, there was a fall of EC and content of available nutrients in systems P and C with both cultivated plants. Between these two fertilization systems, there were not differences in EC (range 0.3–0.6 $mS.cm^{-1}$) and content of available N (20–60 $mg.l^{-1}$) and K (100–430 $mg.l^{-1}$). Marked differences were in the content of available P: system P 15–150 $mg.l^{-1}$, system C 40–190 $mg.l^{-1}$. The lower values of all available nutrients

Table 6. pH value, electric conductivity (EC) and content of available nutrients in substrates before fertilizer application (only with limestone), optimum range for woody ornamentals (experiment 1999)

Substrate	BD ($g.l^{-1}$)	pH	EC ($mS.cm^{-1}$)	$N\text{-}NH_4$	$N\text{-}NO_3$	P	K	Ca
				($mg.l^{-1}$ substrate)				
A	140	5.4	0.19	20	4	7	21	596
B	230	5.5	0.26	30	5	33	298	902
C	210	5.8	0.54	13	6	14	160	973
D	350	5.6	0.16	14	7	17	105	1470
E	330	7.1	0.51	36	13	136	843	3259
F	230	6.4	0.44	46	5	71	504	1434
G	300	6.5	0.43	39	6	32	647	2194
Optimum	200–400	5.5–6.5	> 1.2	ΣN 150–240		40–120	120–340	1300–2800

Table 7. Physical properties of growing substrates (experiment 2000)

Substrate	BD ($g.l^{-1}$)	TP	WPC	AS	P_C	P_S	P_N
				(% vol.)			
A	130	90.7	72.7	18.0	63.8	13.5	13.4
B	230	85.3	65.2	20.1	54.5	14.8	16.0
C	120	93.1	54.7	38.4	44.2	18.1	30.8
D	140	91.8	67.5	24.3	55.2	18.2	18.4
E	190	88.4	71.0	17.3	61.4	13.5	13.5
F	230	86.4	53.6	32.8	43.7	17.1	25.7
G	190	89.8	64.4	25.5	58.5	9.3	22.0
Optimum	150–400	80–90	50–65	20–30	40–50	15–25	10–20

BD – bulk density, TP – total porosity, WPC – water pore capacity, AS – air space, P_C – capillary pore space, P_S – semicapillary pore space, P_N – noncapillary pore space, optimum for growing substrate

were estimated in substrates A and D, upper values in substrates E and F. In some cases, there were changes in pH, increase 0.5–0.8 in substrates B and C.

Evaluating the growth of *Pyracantha* plants there were significant differences between fertilization systems, substrate types (Table 10) and variants (Figure 1). From the fertilization systems (Table 10), the best one was the application of CRF Osmocote exact 5–6 (O). Plants of good quality with worse growth parameters according to the system O were using systems S, P and C. The worst results were in system H (using top dressing). As far as the types of substrates are concerned the best growth parameters were with substrates G and E, the second group consists of substrates F and B and the third of substrates C, D and A. In the variants (Figure 1) lower fresh weight of plants (in the range of 30–41 g) was in system H (substrates A, C, D, F), P (E) and C (C, D A B) and higher fresh weight of plants (in the range of 48–58 g) was in system O (substrates G, E, F, B, A), H (G), P (B, A), C (F, G, E) and S (B, G).

Evaluating the growth of *Thuja* plants there were no significant differences between fertilization systems and substrate types (Table 10) and variants (the range of increments in variants was 23.6–29.8 cm). The worst results (without significant differences) were in the fertilization system H (Table 10) similarly as with *Pyracantha* plants.

Experiment 2000

Differences in the physical properties (Table 7) of tested substrates were influenced by used components. The peat substrate A had the lowest bulk density (BD) connected with high porosity and water pore capacity (WPC) as in 1999. Low BD and high porosity were evident in peat bark substrates with wood fibres Cultifibre, in changed types of substrates in comparison with the year 1999. Substrate D had similar water and air capacity as peat substrate; substrate C with 30% vol. of Cultifibre had high air capacity. Other substrates had higher BD and

Table 8. pH value, electric conductivity (EC) and content of available nutrients in components (experiment 2000)

Component/ used in substrate	BD ($g.l^{-1}$)	pH	EC ($mS.cm^{-1}$)	$N-NH_4$	$N-NO_3$	P	K	Ca
						($mg.l^{-1}$ substrate)		
White peat/A	95	3.8	0.20	13	6	3	12	80
White peat/CD	100	3.8	0.23	19	5	4	23	78
Black peat/A	160	4.1	0.12	16	7	3	16	160
Bark I/B	280	5.3	1.38	353	252	30	593	867
Bark II/E	230	5.8	0.36	9	16	52	414	1012
Bark III/CD	240	4.9	0.43	26	12	23	436	545
Bark IV/FG	200	5.3	0.24	60	4	26	310	740
Sawdust/D	80	4.5	0.15	14	3	2	37	68
Cultifibre/CD	100	4.6	0.08	4	5	6	60	99
Toresa/F	90	5.2	0.25	21	16	7	81	204
Compost/FG	430	6.9	0.53	60	120	119	735	4763

BD – bulk density

Table 9. pH value, electric conductivity (EC) and content of available nutrients in substrates before fertilizer application (only with limestone), optimum range for woody ornamentals (experiment 2000)

Substrate	OH ($g.l^{-1}$)	pH	EC ($mS.cm^{-1}$)	$N\text{-}NH_4$	$N\text{-}NO_3$	P	K	Ca
				($mg.l^{-1}$ substrate)				
A	130	5.02	0.41	39	22	5	62	572
B	230	5.47	1.15	255	207	19	395	1143
C	120	5.63	0.36	20	4	4	113	852
D	140	5.69	0.35	24	4	5	130	1014
E	190	5.24	0.36	2	11	22	232	863
F	230	6.07	0.36	58	18	31	399	1453
G	190	4.66	0.48	17	49	3	181	985
Optimum	200–400	5.5–6.5	< 1.2	ΣN 150–240		40–120	120–340	1300–2800

slightly lower porosity. Peat bark substrates E and B had low air capacity; substrate E had the highest water capacity of all substrates. The bark used for these two substrates was much decomposed with lowered air capacity. In spite of the mentioned differences, all tested substrates had suitable physical properties; only low air capacity of some of them (A 1999, A 2000, D 1999, E 2000) could be disadvantageous during rainy periods or with excessive irrigation.

Chemical properties of the substrate components (Table 8) corresponded with customary values. Peat and wood components (sawdust, Cultifibre and Toresa) were poor in available nutrients and had low EC values. Composted bark had higher content of P, Ca and especially K. Compost had the highest content of all nutrients, high pH corresponded with high content of Ca. Bark I had surprisingly high content of both forms of available nitrogen, this was caused by high rates of nitrogen applied during composting.

In substrates without preplant fertilization, only with pH correction by limestone (Table 9) the content of available nutrients and EC had common values. With the exception of substrate B with bark I, which had very high content of available nitrogen and high EC. Substrate F with compost had relatively high content of available P and $N\text{-}NH_4$. But the content of P in all substrates with the same composition was lower than in the year 1999 (Table 6). Substrates containing more bark (all substrates except substrate A) had high content of K. But the highest content (< 400 mg $K.l^{-1}$, Table 9) was lower than in the year 1999 (> 500 mg $K.l^{-1}$, Table 6). Peat substrate A and substrate G with low rate of limestone had low pH, the highest pH (6.1) and higher content of available Ca were in peat free substrate F with the compost.

After application of soluble fertilizers PG MIX in rate 1 $g.l^{-1}$ substrate (systems P and N) and Hydrokomplex in rate 2 $g.l^{-1}$ substrate (H), EC and content of available nutrients increased. Higher increase was in system H. EC

Table 10. The effect of fertilization system and type of growing substrate on *Thuja occidentalis* and *Pyracantha coccinea*; results of two-way ANOVA, means followed by the same letter are not significantly different within one factor and parameter according to Duncan's Multiple Range test, $p < 0.05$, $n = 40$ per treatment (experiment 1999)

Factor	Parameter/date of evaluation			
	Thuja increment (cm)		*Pyracantha* (19.–20. 9.)	
	28. 6.	19. 9.	shoot length (cm)	fresh weight (g)
	Fertilization system			
P	8.0 a	27.7 a	69.1 b	46.3 b
C	7.9 a	27.5 a	67.9 b	44.2 b
H	7.7 a	24.2 a	62.6 c	41.0 c
S	7.5 a	27.2 a	67.5 b	44.4 b
O	8.2 a	27.1 a	71.6 a	49.8 a
	Substrate			
A	8.3 a	26.9 a	64.4 c	42.2 b
B	7.7 a	25.9 a	68.5 ab	47.2 a
C	8.0 a	26.9 a	64.7 c	41.4 b
D	7.8 a	27.0 a	66.8 bc	41.4 b
E	7.8 a	26.2 a	69.9 a	47.0 a
F	7.4 a	26.9 a	69.2 ab	46.5 a
G	8.1 a	27.4 a	70.8 a	50.4 a

Table 11. The effect of fertilization system and type of growing substrate on *Thuja occidentalis* and *Pyracantha coccinea*; results of two-way ANOVA, means followed by the same letter are not significantly different within one factor and parameter according to Duncan's Multiple Range test. $p < 0.05$, $n = 40$ per treatment (experiment 2000)

Factor	Parameter/date of evaluation			
	Thuja increment (cm)		*Pyracantha* (19.–20. 9.)	
	28. 6.	19. 9.	shoot length (cm)	fresh weight (g)
		Fertilization system		
P	8.3 a	22.3 a	39.4 b	55.1 c
C	8.1 ab	22.4 a	42.0 b	57.4 b
H	8.3 a	20.4 c	39.5 b	59.3 b
S	8.3 a	22.0 ab	42.0 b	59.4 b
O	7.8 b	21.5 b	46.0 a	63.0 a
		Substrate		
A	8.6 b	21.4 b	27.8 f	51.8 e
B	7.6 c	19.6 c	53.0 a	59.6 bc
C	7.5 c	21.9 b	42.9 cd	60.7 bc
D	7.2 d	21.7 b	35.1 de	58.5 cd
E	8.6 b	22.2 ab	46.0 bc	61.4 ab
F	9.1 a	22.3 a	49.5 ab	63.6 a
G	8.5 b	22.9 ab	38.2 e	56.5 d

values and content of available nutrients were as follows: system H: 1.3–2 $mS.cm^{-1}$, 30–400 mg $N.l^{-1}$, 40–110 mg $P.l^{-1}$, 260–650 mg $K.l^{-1}$, systems P, N: 0.7–1.5 $mS.cm^{-1}$, 20–500 mg $N.l^{-1}$, 50–85 mg $P.l^{-1}$, 160–400 mg $K.l^{-1}$. The lower values were estimated in substrate C and D (EC, content of N and P), and A (content of K). Higher values were estimated in substrates B (EC, content of N and K) and F (content of P and K). The content of N was in most substrates (except C, D and B) in the range of 200–300 $mg.l^{-1}$.

The high content of available nitrogen in substrate B was influenced by bark I with high content of N (Table 8). There was no increase due to the rates of N used in preplant fertilizers (Table 3). This may be caused by possibilities of nitrogen tie-up associated with biological sorption in this substrate during the time (2 weeks) between application of fertilizers and sampling. Substrates C and D, with wood components (fibres, sawdust) had the lowest content of available N and no or very low increase of N after fertilizing. In this case, there was also tie-up of nitrogen associated with biological decompositions of these components. After application of fertilizers media pH lowered by 0.1–0.8, the greatest fall from 6.1 to 5.3 was in substrate F.

In the second half of the vegetation, there was a fall of EC and content of available nutrients in systems K and N with both cultivated plants. Values of EC were 0.4–0.7 $mS.cm^{-1}$ and the range of available to plants was 30–70 mg $N.l^{-1}$, 15–60 mg $P.l^{-1}$ and 150–300 mg $K.l^{-1}$. The low values were estimated mostly in substrates C, D and A. The lower content of available nitrogen, especially $N\text{-}NO_3$ was in substrates C

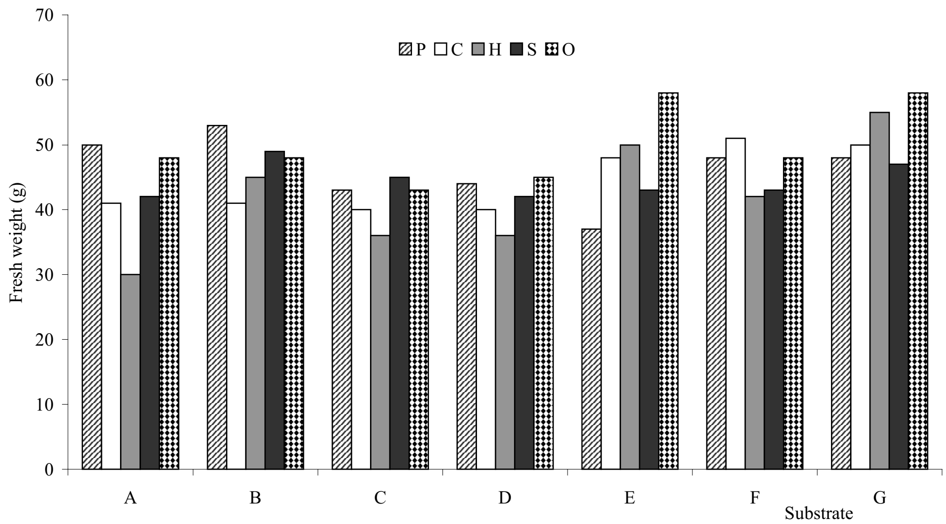

Figure 1. The effect of fertilization system (P, C, H, S, O) and type of growing substrate (A–G) on *Pyracantha* plants fresh weight (experiment 1999)

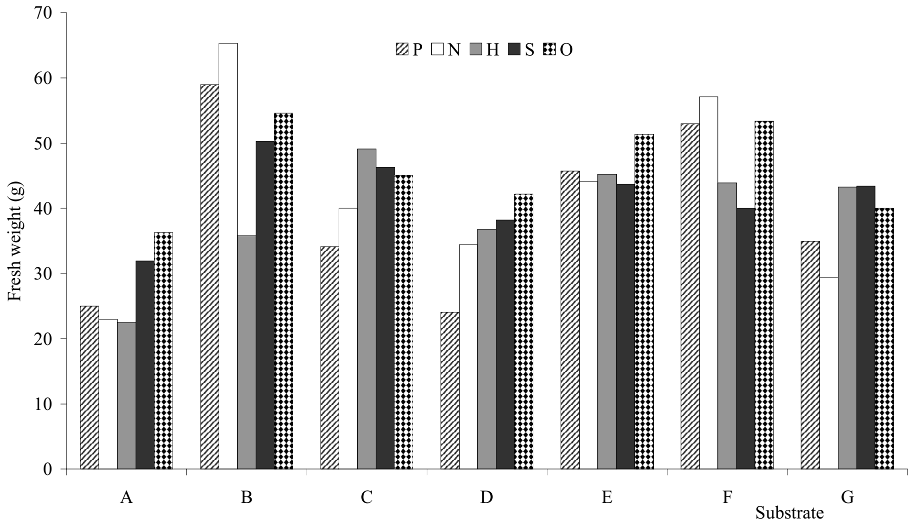

Figure 2. The effect of fertilization system (P, N, H, S, O) and type of growing substrate (A–G) on *Pyracantha* plants fresh weight (experiment 2000)

and D with wood components. The highest content of available P and K was in substrate F with compost.

The composition of substrates and the fertilization systems influenced the growth of tested plants. The reaction was partly different. In evaluating the growth of *Pyracantha* plants there were significant differences between fertilization systems, substrate types (Table 11) and variants. Application of CRF Osmocote 5–6 (system O) was as in the year 1999 the best fertilization system (Table 7). Among the other systems, there were no significant differences. Systems N and S were slightly better (not significantly) than systems K and H. In the year 1999, the system H (using top dressing) was significantly the worst. In the year, 2000 there should be positive effect of earlier (two weeks) second application (Table 3).

The best growth parameters were in substrates B and F, the second group consists of substrates E and C and the third one of substrates D, G and A. The worst results were with peat substrate A. The fresh weight of growth was very influenced by the substrate, the best growth was in substrates with high content of available nutrients – peat bark substrate B with high content of available N, substrate F with compost. Fresh weight of *Pyracantha* plants in substrate B was twice of that in substrate A. Substrates B, F and E were also good in the year 1999, and peat substrate A belongs to the worst ones, but the differences were not so big. In case of non-peat substrate F there was a positive effect of combination of compost with low air capacity and wood fibres Toresa with high air capacity. Peat bark substrates amended only with wood fibres or sawdust (C, D – 2000) had high air capacity and risk of N fixation. However, these substrates were in most cases the same or better than peat substrate. The experiments showed good results with substrates with part or total peat substitution. Composted bark and compost (composted green waste materials and wood chips) proved to be suitable alternative components.

Evaluating the variants in comparison with the year 1999 (Figure 1) there was bigger influence of substrates (Figure 2). Lower fresh weight of plants (in the range of 22.5–34.1 g) was in substrates A (systems H, N, P, S), D (P), G (N) and C (P) and higher fresh weight of plants (in the range of 50.3–65.3 g) were by substrates B (systems N, P, O), F (G), P (N, O, P) and E (O). In substrates A, C, D, E and G, both systems with liquid feeding (P, N) were worse than systems O and S. Only in two substrates (B, F) systems P and N were similar or better than O. System with top dressing (H) was similar (substrates A, C) or better (substrates D, G) than systems P and N.

In evaluating the growth of *Thuja* plants there were significant differences between fertilizing systems, substrate types (Table 11) and variants. Substrates F, E and G showed the best growth parameters at the end of experiment, the second group consists of substrates C, D and A and the third one of substrate B. Peat substrate A belongs to the worse ones and substrate B was the worst. The differences between the best and the worst substrates were not so big as with *Pyracantha* plants. The high content of available nitrogen and relatively high EC in substrate B had negative influence on *Thuja* plants, in contrast to *Pyracantha* plants, which has higher demand for nutrients. Substrates with alternative components might have high natural or during composting acquired content of nutrients. In some cases, the content of K (peat bark substrates, substrates with compost) or N (peat bark substrate B – 2000) was high (above optimum rate). In systems, using soluble pre-plant fertilizing it would be better to use only NP and P fertilizers, respectively. When using peat alternative components more attention has to be given to chemical analyses.

The rank of the fertilization systems (Table 11) was N, K, S, O and H, the differences were small. The system H was also worst in 1999; the difference in comparison with the best system was bigger.

With each substrate, there were small differences among fertilization systems. System H was slightly worse in substrates B, D, A and G. Lower plant increments (in the range of 18.4–20.8 cm) were with substrate B (systems H, O, S, P, N), D (H), A (H, O) and G (H) and higher plant increments (in the range of 22.8–23.9 cm) were with substrate G (systems N, P), F (P, N, S, O) and E (N).

It is interesting, that system O with several substrates (B, A, G) had in the year 2000 worse results in comparison with *Pyracantha* and *Thuja* plants in the year 1999. It might be caused by the course of weather in the first part of growing period. The average daily temperatures and rainfall in 2000 were: 16.1°C and 39.9 mm in May, 18°C and 39.7 mm in June, 15.1°C and 86.2 mm in July and 19.2°C and 44.5 mm in August. To make comparison the average daily temperatures and rainfall in 1999 were: 14°C and 37.9 mm in May, 15.1°C and 47.1 mm in June, 18.7°C and 53.7 mm in July and 17.4°C and 34.7 mm in August. The high temperatures in May and June in 2000 supported the release of nutrients from CRF and subsequent rainy period (July/August) might caused nutrient leaching from the substrate. In the second part of the vegetative period, when the increment of *Thuja* plants was about 2/3 of the total increment, the plants might not have optimal nutrition with CRF and systems with liquid feeding had better results.

Nevertheless, application of CRF Osmocote was the most reliable fertilization system in all experiments because it gave good or average results according to growing substrates. It decreased negative properties of some substrates (nitrogen immobilisation). There were also good results with the system using SRF Silvamix forte. Systems based on liquid feeding (C, P and N) were less reliable, with some substrates they showed very good results; with others (peat substrate, peat bark substrates with wood fibres) they were bad. Similar results were achieved with top dressing of granulated fertilizer.

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ABSTRAKT

Vliv systému hnojení a pěstebního substrátu na růst okrasných dřevin v kontejnerech

Pět systémů hnojení a sedm typů pěstebních substrátů bylo ověřováno u dvou druhů okrasných dřevin s odlišnými nároky na živiny (*Thuja occidentalis* a *Pyracantha coccinea*), pěstovaných ve dvoulitrových kontejnerech. Pokus byl opakován ve dvou vegetačních obdobích. Jako nejspolehlivější se projevila aplikace hnojiva s řízeným uvolňováním, s nímž bylo dosaženo velmi dobrých nebo alespoň průměrných výsledků v závislosti na použitém substrátu. Statisticky průkazné rozdíly mezi aplikací tohoto typu hnojiva a ostatními systémy hnojení byly nalezeny u rostlin *Pyracantha*. Dobrých výsledků bylo rovněž dosaženo při použití pomalu působícího hnojiva s doplňkovým přihnojováním dusíkem. Méně spolehlivé byly systémy s přihnojováním živnými roztoky, v některých substrátech dávaly výsledky velmi dobré, v jiných (rašelinový substrát, rašelinokůrové substráty s dřevními vlákny) špatné. Obdobné výsledky byly zaznamenány u systému hnojení s povrchovou aplikací granulovaného hnojiva. Ze substrátů se osvědčily směsi s komponentami s vyšším obsahem živin – rašelinokůrové, rašelinokůrové s kompostem, substrát bez rašeliny na bázi kompostované kůry kompostu a dřevních vláken. Statisticky průkazné rozdíly mezi těmito typy substrátů a substrátem rašelinovým, případně rašelinokůrovým s komponentami na bázi dřeva byly zjištěny jak u rostlin *Thuja*, tak především u rostlin *Pyracantha*, které mají vyšší nároky na živiny. Pokusy prokázaly, že směsi rašeliny s alternativními komponentami nebo substráty bez rašeliny mohou dávat lepší výsledky než substráty rašelinové.

Klíčová slova: organické substráty; rašelina; alternativní komponenty; systémy hnojení; růstová reakce; *Thuja occidentalis*; *Pyracantha coccinea*

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