Effect of slow release fertilizers on container-grown woody plants

F. Šrámek, M. Dubský

Silva Tarouca Research Institute for Landscape and Ornamental Gardening, Průhonice, Czech Republic

ABSTRACT: Slow-Release Fertilizers (SRF) Silvamix Forte and Silvagen were tested in two-year experiments with container-grown woody plants (*Pyracantha coccinea*, *Thuja occidentalis*). Several fertilizing systems were compared: preplant application of SRF into substrate as the sole nutrient source for a two-year period, preplant application of SRF and soluble fertilizer (PG Mix), and preplant application of SRF and soluble fertilizer together with additional fertilizing by solution of nitrogen fertilizer during both growing periods. A system with controlled-release fertilizer (CRF) Osmocote 5–6 was chosen as a control variant; it was incorporated into substrate before planting in the first year and top-dressed in the second year. CRF Plantacote 6M (mixed into substrate before planting and top-dressed in the second year) and Osmocote 16–18 applied only before planting were tested, too. The experiments showed that SRF Silvamix Forte and Silvagen give results comparable with CFR provided that they were incorporated together with soluble fertilizer dose and plants were fertilized by solution of nitrogen fertilizer during both growing periods.

Keywords: slow release fertilizers; controlled-release fertilizer; woody plants; growth response

Use of slow-release fertilizers (SRFs) and controlled-release fertilizers (CRFs) represents an advantageous alternative to the traditional fertilization programs based on preplant application of soluble fertilizer and liquid fertilization throughout the growing cycle (Shaviv 2001). It avoids high salt level in the growing media, improves nutrients use efficiency, reduces nutrient leaching losses, and reduces labour cost (Shaviv 2001; Sharma 1979; Rathier, Frink 1989; Wang, Alva 1966; Catanzaro et al. 1998). It provides a very useful, inexpensive and simple way to supply nutrients, mainly for low-technology nurseries (Oliet et al. 2004). Preplant application of CRFs or SRFs ensures adequate nutrition during the entire growing cycle (Johnson et al. 1981; Oliet et al. 2004; Worrall et al. 1987), a great advantage over the liquid fertilization is obvious during periods of frequent and heavy rains (Gouin, Link 1973). Principal factors affecting the release of nutrients from CRFs are temperature and time (Husby et al. 2003; Hinklenton, Cairns 1982; Lamont et al. 1987; Kochba et al. 1990); there are many CFR products differing in formulations, longevity and also in nutrient release rate dynamics. These properties are set during CRF preparations. Release of nutrients from SRFs is not so well controllable; besides temperature and time, the other factors such as fertilizer particle size, soil (substrate) moisture content, pH, and microbial activity are of great importance (Shaviv 2001; Tlustoš, Blackmer 1992). Despite of this disadvantage SRFs represent a reasonable and mostly cheaper alternative to CRFs.

In the Czech forest nurseries and forest plantations a group of Silvamix fertilizers is frequently used. They contain all nutrients in slow-acting forms. Nitrogen is predominantly in the form of urea-aldehyde condensates (ureaform) and sparingly soluble potassium-magnesium phosphates guarantee a slow effect of other essential nutrients. The Silvamix fertilizers are assigned mainly for application in forest nurseries (Salaš et al. 2000) and in plantings of forest (Burda 2003), ornamental (Bulíř, Dubský 1998) and fruit-bearing woody species. They can be used for fertilizing container-grown plants as an alternative to CRFs, but sufficient data concerning such a comparison are not available. Silvamix fertilizers release nutrients during a period longer than one growing season and it was found that they could not release nitrogen regularly during two vegetative seasons if they were applied in rates recommended by the manufacturer (5 g/litre of substrate). Salaš (2003) suggests a supplementary application of nitrogen fertilizer in the second growing season, but according to other studies (Dubský, Kubíček 1999)

Silvamix fertilizers do not cover the whole plant requirement for nitrogen in the first year, either.

The objective of this study was to determine whether Silvamix SRFs (Silvamix Forte, Silvagen) are sufficient as the sole source of nutrients or whether it is necessary to apply them together with soluble fertilizer before planting and eventually with additional fertilizing with liquid fertilizers throughout the growing period and whether such fertilizing systems are comparable with CRFs (Osmocote, Plantacote).

MATERIALS AND METHODS

The fertilizing systems were tested in two two-year experiments with container-grown woody plants (*Thuja occidentalis, Pyracantha coccinea*); basic data of experimental design are shown in Table 1.

In the first experiment (1999–2000) several variants with tabletted SFRs Silvamix Forte (the contents of N, P_2O_5, and K_2O were 17.5, 17.5, and 10.5 %, respectively) and Silvagen (25/5/10) were compared. Both Silvamix fertilizers differed in total nutrient content and in the proportion of water soluble and insoluble nitrogen. According to the manufacturer, Silvamix Forte contains 17.5% of total nitrogen, including 7% of water insoluble N (20°C) and 3.5% of hot water insoluble N (100°C); Silvagen contains 25% of total nitrogen, including 14% of water insoluble N and 6.9% of hot water insoluble N. Two five-gram tablets of Silvamix fertilizer were put in each two-litre container under root system during planting. For calculation of nitrogen added by Silvamix Forte or Silvagen, water insoluble nitrogen was not taken into account (Tables 2 and 3) because it is practically unavailable for plants. Silvamix fertilizers were applied as the sole nutritional source (var. F, G) or together (var. FP, GP) with soluble fertilizer PG Mix (14/16/18, in a dose of 1 g/l of substrate) incorporated in the substrate before planting to ensure nutritional demand during the first vegetative stage. Additional application of 0.2% solution of nitrogen fertilizer DAM (390 g N/l) during vegetative season was used in some variants (Table 2). One dose of N fertilizer DAM (75 ml of 0.2% solution per litre of substrate) added 58 mg N/l of substrate. Supplementary liquid fertilizing started seven weeks after planting when the soluble part of nitrogen in Silvamix fertilizer was used up according to the results of the growth and lysimetric experiments (Dubský, Kubíček 1999; Kubíček, Hegner 1992). Applications proceeded till 10th August, frequency of application was based on practical experience with Silvamix Forte (Dubský, Kubíček 1999). Considering the higher nitrogen content in Silvagen, variants with this fertilizer had a lower frequency of supplementary liquid fertilizing than variants with Silvamix Forte in 1999 (Table 2). In the second year only the experiment with *Pyracantha* plants continued. The liquid fertilizing started at the end of May and continued till 10th August, the frequency was the same for both Silvamix fertilizers, two for variants GP2 and FP3, four for variants GP3 and FP5. Variants with CRF Osmocote Plus 5–6 (15/10/12) and Plantacote 6M (15/10/15) each in the dose of 4 g/l of substrate were included in this experiment for comparison; in the first year the fertilizers were incorporated in the substrate before planting, in the second year they were top-dressed. The survey of all variants and rates of added nutrients is shown in Table 2.

Table 1. Experimental design

Term	1999–2000	2000–2001
Plants	*Thuja occidentalis* L. cv. Smaragd (0/1/1); *Pyracantha coccinea* Roem. cv. Red Column (0/2/0)	
Potting	May 12, 1999	April 12, 2000
Containers	height 13 cm, volume 2 l	
Substrate	peat (white peat 70% vol., black peat 30% vol.), 5 kg limestone/m^3	
Irrigation	sprinkler irrigation	
Transplanting	–	*Thuja* – April 1, 2001, containers: height 17 cm, volume 4 l
Variants	10 (see Table 2)	4 (see Table 3)
No. of replication	5	5
No. of plants in each replicate	10	*Pyracantha* 9, *Thuja* 10
Evaluation of plants	*Thuja* (height): Apr. 20, July 2, Sept. 16, 1999 *Pyracantha* (height, fresh weight): Sept. 16, 1999, Oct. 16, 2000	*Thuja* (height): Apr. 20, July 2, Sept. 12, 2000, Apr. 17, July 11, Sept. 5, 2001; *Pyracantha* (height, fresh weight): Sept. 16, 2000, Oct. 2, 2001

Table 2. Fertilizing systems and rate of applied nutrients in the first experiment (1999–2000): fertilizer dose (g/l), frequency of liquid fertilizing (No.) and sum of nutrients (mg/l)

Variant	1999						2000			Sum 1999–2000		
	Osmoc. 5–6	Plantacote	Silvagen	Silvamix F.	PG Mix	Liquid fert.	Osmoc. 5–6	Plantacote	Liquid fert.	N	P	K
O	4	–	–	–	–	–	4	–	–	1,200	350	800
P	–	4	–	–	–	–	–	4	–	1,200	350	990
G	–	–	5	–	–	–	–	–	–	905	110	415
F	–	–	–	5	–	–	–	–	–	700	385	435
GP	–	–	5	–	1	–	–	–	–	1,045	180	565
FP	–	–	–	5	1	–	–	–	–	875	455	585
GP2	–	–	5	–	1	2	–	–	2	1,277	180	565
GP3	–	–	5	–	1	3	–	–	3	1,451	180	565
FP3	–	–	–	5	1	3	–	–	2	1,130	455	585
FP5	–	–	–	5	1	5	–	–	3	1,362	455	585

The second experiment (2000–2001) was a little changed, taking into account the results of the first experiment. SRFs Silvamix Forte and Silvagen (5 g/l of substrate) were applied together with soluble fertilizer PG Mix (1 g/l of substrate) and with an additional liquid fertilizing by nitrogen fertilizer DAM throughout the growing cycle that started eight weeks after planting. In the first year there were three applications of liquid fertilizer, in the second year there were four applications. CRF Osmocote exact standard 5–6 was used as a new product substituting Osmocote plus 5–6. It was applied in the rate 4.5 g/l, in the first year it was incorporated into the substrate before planting, in the second year it was top-dressed. Fertilizer Osmocote plus 16–18 with a longer release period assigned for a two-season use was applied in the substrate before planting (9 g/l) only in the first year.

The above-mentioned scheme summarized in Table 3 fully corresponds to the experiment with *Pyracantha* plants. The experiment with *Thuja* plants was the same as for the fertilizer doses and the amount of added nutrients on one plant basis. As for nutrient doses calculated on substrate volume basis they were the same in 2000 and half in 2001, as compared to the values in Table 3, because the *Thuja* plants were transplanted into containers with double volume that year.

At the end of each growing season the height and fresh weight of *Pyracantha* plants were estimated. The height of *Thuja* plants was measured three times in each growing season (Table 1) and seasonal and semiseasonal height increments were calculated. All the data sets were tested for normality and analyzed by one-way analysis of variance; two-way analysis of variance was used for evaluation of the effects of SRF type and the way of additional fertilizing in the first experiment. The significance level $P = 0.05$ was used and significant differences between means were evaluated using Duncan's Multiple Range Test.

Table 3. Fertilizing systems and rate of applied nutrients in the second experiment (2000–2001) with *Pyracantha* plants: fertilizer dose (g/l), frequency of liquid fertilizing (No.) and sum of nutrients (mg/l)

Variant	2000						2001			Sum 2000–2001		
	Osmoc. 5–6	Osmoc. 16–18	Silvagen	Silvamix F.	PG Mix	Liquid fert.	Osmoc. 5–6	Osmoc. 16–18	Liquid fert.	N	P	K
O	4.5	–	–	–	–	–	4.5	–	–	1,350	360	670
OD	–	9	–	–	–	–	–	9	–	1,350	360	750
G3	–	–	5	–	1	3	–	–	4	1,461	180	565
F3	–	–	–	5	1	3	–	–	4	1,256	455	585

Table 4. Evaluation of the first experiment. Values with the same letter are not significantly different according to Duncan's Multiple Range test, $P = 0.05$

Variant	*Pyracantha*				*Thuja* height increment	
	1999		2000		1999	
	fresh weight (g)	height (cm)	fresh weight (g)	height (cm)	Apr–July (cm)	Apr –Sept (cm)
O	57.3 ab	70.4 ab	77.3 ab	74.4 a	7.0 a	25.8 a
P	55.2 ab	72.4 a	84.0 a	74.5 a	7.9 a	26.3 a
G	34.5 d	59.1 fg	44.3 d	50.7 b	5.6 c	26.8 a
F	31.2 d	57.4 g	25.2 e	46.7 b	5.8 bc	27.4 a
GP	48.6 bc	65.2 cd	61.2 c	69.2 a	6.9 ab	26.6 a
FP	45.6 d	62.0 ef	34.5 de	47.9 b	7.5 a	26.8 a
G2	49.0 bc	63.4 de	74.2 ab	74.0 a	6.5 abc	27.9 a
G3	56.4 ab	67.8 bcd	65.4 bc	76.2 a	7.5 a	28.1 a
F3	55.9 ab	67.5 bcd	61.0 c	73.9 a	6.6 abc	27.0 a
F5	61.2 a	66.7 bcd	67.7 bc	73.3 a	6.9 ab	26.2 a

RESULTS AND DISCUSSION

The first experiment (1999–2000)

In the first year (1999) the best growth of *Pyracantha* plants was in substrate with CRF (var. O, P). Comparable results were obtained with SRF but only in cases when they were combined with additional preplant fertilizing with soluble fertilizer (PG Mix) and additional fertilizing with liquid nitrogen fertilizer (DAM) throughout the vegetative period (var. F5, F3, G3). Variant G2 with two additional liquid fertilizing gave slightly worse results in spite of high total nitrogen content in Silvagen fertilizer (Tables 2 and 4). The worst growth was estimated in variants FP and GP without liquid fertilizing and mainly in variants F and G with no additional fertilizing. Comparing the variants with the same additional fertilizing (F × G, FP × GP, F3 × G3), differences were found between both used SRF – Silvamix Forte and Silvagen, although a significant difference was only observed between var. GP and FP (Table 4). In the second year (2000) the best growth was estimated in variants O and P with repeated application of CRF and in G2. Comparable results were obtained with Silvamix fertilizers combined with additional nitrogen fertilizing F5 and G3, slightly worse was F3. When comparing variants without liquid fertilizing (F, G, FP, GP), Silvagen gave better results than Silvamix Forte (Table 4) probably because of higher N content (Table 2). The effect of individual factor (type of fertilizer, supplementary fertilizing) was more apparent when the results from variants F, G, FP, GP, F3, and G3 were analyzed by the two-way analysis of variance. The supplementary fertilizing had a statistically significant effect in the first and in the second year, whereas the type of fertilizer in the second year only (Table 5).

Silvamix contains three ureaform fractions: cold water soluble, hot water soluble and hot water in-

Table 5. Effect of two factors – fertilizer type and additional fertilizing on *Thuja* and *Pyracantha* growth in the first experiment, results of two-way analysis of variance, type of fertilizer: Silvamix Forte (F) and Silvagen (G), additional fertilizing: without (–), PG Mix added before planting (P), and PG Mix + supplementary N fertilizing (P + DAM). The values with the same letter are not significantly different within one factor, $P = 0.05$

Factor	*Thuja* 1999 height increment		*Pyracantha* 1999		*Pyracantha* 2000	
	Apr.–July (cm)	Apr.–Sept. (cm)	height (cm)	fresh weight (g)	height (cm)	fresh weight (g)
Type of fertilizer						
F	6.6 a	27.2 a	63.3 a	42.2 a	56.0 b	42.5 b
G	6.9 a	27.1 a	64.0 a	46.5 a	64.9 a	56.6 a
Additional fertilizing						
–	5.7 a	27.1 a	58.2 c	32.8 c	48.7 c	34.8 c
P	7.6 a	26.7 a	63.6 b	44.0 b	58.6 b	48.0 b
P + DAM	7.1 a	27.6 a	67.6 a	56.2 a	77.7 a	66.6 a

Table 6. Evaluation of the second experiment. Values with the same letter are not significantly different according to Duncan's Multiple Range test, $P = 0.05$

Variant	*Pyracantha*				*Thuja* – increase in height				
	2000		2001		2000		2001		total
	fresh weight (g)	height (cm)	fresh weight (g)	height (cm)	Apr.–July (cm)	Apr.–Sept (cm)	Apr.–July (cm)	Apr.–Sept (cm)	(cm)
O	62.0 a	41.5 b	97.4 a	69.2 a	10.4 c	21.0 b	19.2 a	31.0 ab	51.9 b
OD	64.0 a	41.1 b	96.2 a	67.6 a	10.7 cd	23.8 a	17.4 b	28.3 c	53.3 b
G3	63.6 a	52.3 a	82.0 a	68.2 a	11.6 ab	23.8 a	19.0 ab	30.3 bc	54.6 ab
F3	64.3 a	54.9 a	79.2 a	70.6 a	11.7 a	23.1 a	20.2 a	33.3 a	57.1 a

soluble. Nitrogen from the first fraction is readily available, nitrogen from the second one is slowly released into the soil, and nitrogen from the third one is practically unavailable (Shaviv 2001; Tlustoš, Blackmer 1992). Therefore when the amount of added nitrogen was calculated (Table 2) only cold water soluble and hot water soluble nitrogen were taken into account and only the variants GP2, GP3, FP3, and FP5 were comparable with O and P. Shaviv (2001) reports that sometimes nitrogen from cold water soluble fraction is released too quickly, but it was not the case of this experiment because the preplant addition of soluble fertilizer had a positive effect on the growth; variants GP and FP were better than G and F, respectively (Table 5).

The experiments with *Pyracantha* plants suggested that the application of Silvamix fertilizers as the sole nutrient source could not ensure a satisfactory plant growth throughout the two-year period as the Silvamix producer claims. It is consistent with previously published results of Dubský and Kubíček (1999) and Salaš (2003).

The first experiment with *Thuja* plants was carried out in 1999. Significant differences in increments were found only at the first evaluation (July 2), when variants F and G without preplant fertilizing with PG MIX gave worse results than the other variants. At the end of the experiment the differences in increments were small and insignificant (Table 4), but the variants F5, F3, and G3 were apparently better in colour and habit. Two-way analysis of variance (Table 5) did not reveal a significant effect of fertilizer type and additional fertilizing in variants with Silvamix (F, G, FP, GP, F3, and G3), either. *Thuja* plants did not have so high requirements for nutrients as *Pyracantha,* which is the reason why the results of both experiments were quite different.

The second experiment (2000–2001)

In the first year there were no significant differences in fresh weight of *Pyracantha* plants; they prospered well both in variants with SRFs and in variants with CRFs, moreover, the highest plants were in variants with SRFs (Table 6).

In the second year significant differences were neither in fresh weight nor in height. As for fresh weight, the order of variants was O > OD > G3 > F3. There was no substantial difference between both SRF treatments (Table 6).

Results of the second experiment with *Thuja* plants were rather different. In the first year the greatest increments of height were estimated in variants with SRF (F3, G3) and Osmocote 16–18 (OD), in the variant with Osmocote 5–6 the increments were lower (Table 6). In the second year Silvamix Forte (F3) and Osmocote 5–6 (O) gave the best results and Osmocote 16–18 (OD) the worst one. The order of variants was F3 > O > G3 > OD. When evaluating the total height increments, *Thuja* plants fertilized with Silvamix Forte and Silvagen were the best, the order of variants was F3 > G3 > OD > O (Table 6).

CONCLUSIONS

Both of the experiments carried out in years 1999–2000 and 2000–2001 indicated that tabletted SRF Silvamix Forte or Silvagen incorporated into substrate in the rate recommended by manufacturer (5 g per 1 l) are insufficient, especially for species with high nutritional demand (*Pyracantha*). They required a supplementary application of soluble fertilizer before planting and a supplementary application of liquid nitrogen fertilizer throughout the vegetative period. With such treatments Silvamix fertilizers give comparable results as CRF (Osmocote, Plantacote). Fertilizer PG Mix incorporated into substrate (1 g/l) before planting and three applications of 0.2% solution of nitrogen fertilizer DAM in the second part of the vegetative period (mid-June to mid-August) proved to be sufficient in the first year; four applications of liquid nitrogen fertilizer can be recommended in the second year (May to mid-August).

Statistically significant differences between Silvamix Forte and Silvagen were found only in several cases. Higher nitrogen content in tablets of Silvagen had a positive effect mainly on *Pyracantha* plants without additional fertilizing during growing season.

No significant differences between controlled-release fertilizers Osmocote plus 5–6 and Plantacote 6M were found. Fertilizer Osmocote 16–18 is suitable for a two-year cultivation; according to the experiments it gave results comparable with repeated application of Osmocote 5–6.

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Received for publication May 17, 2005
Accepted after corrections February 24, 2006

Vliv hnojiv s pozvolným uvolňováním na růst dřevin v kontejnerech

ABSTRAKT: Hnojiva s pozvolným uvolňováním (SRF) Silvamix Forte a Silvagen se testovala v dvouletých pokusech s dřevinami v kontejnerech (*Pyracantha coccinea*, *Thuja occidentalis*). Porovnávalo se několik systémů hnojení: samotná SRF aplikovaná do substrátu před sázením rostlin jako jediný zdroj živin pro celé dvouleté období, SRF aplikovaná do substrátu spolu s rozpustným hnojivem (PG Mix) a SRF spolu s rozpustným hnojivem a přihnojováním roztokem dusíkatého hnojiva v průběhu obou vegetačních období. Jako kontrolní byl zvolen systém s hnojivem s řízeným uvolňováním (CRF) Osmocote 5–6 aplikovaným v prvním roce do substrátu před sázením rostlin a v druhém roce na povrch substrátu. Rovněž se testovala hnojiva CRF Plantacote 6M (aplikace do substrátu a v druhém roce na povrch) a Osmocote 16–18 aplikované jednorázově před sázením. Pokusy prokázaly, že hnojiva Silvamix Forte a Silvagen jsou srovnatelná s hnojivy s řízeným uvolňováním, pokud jsou aplikována spolu se „startovací" dávkou rozpustného hnojiva a rostliny jsou v průběhu obou vegetačních období přihnojovány roztokem dusíkatého hnojiva.

Klíčová slova: hnojiva s pozvolným uvolňováním; hnojiva s řízeným uvolňováním; dřeviny; růstová reakce

Corresponding author:

RNDr. František Šrámek, CSc., Výzkumný ústav Silva Taroucy pro krajinu a okrasné zahradnictví,
252 43 Průhonice, Česká republika
tel.: + 420 296 528 336, fax: + 420 267 750 440, e-mail: sramek@vukoz.cz