Reduction of Nutrient Run-Off by the Use of Coated Slow-Release Fertilizers on Two Container-Grown Nursery Crops

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Abstract

The agricultural district of Pistoia (Tuscany, Italy) is one of the most important sites in Europe for the production of Hardy Ornamental Nursery Stock (HONS). One of the main problems of this sector is the environmental impact of the pot cultivation, mainly due to an incorrect irrigation scheduling that leads to high nitrogen and phosphorus losses. The aim of this research has been to compare the effects of the traditional fertigation versus new fertilization strategies, based on the use of controlled slow-release fertilizers (CRFs), on plant growth and on nitrogen and phosphorus run-off in two container HONS species (*Photinia* x *fraseri* and *Prunus laurocerasus*). Every week, plant height, cumulate irrigation and drainage volume were measured on four replicates for each treatment and species. Every four weeks two average samples of drainage water and irrigation water for each treatment and species were analysed, determining total nitrogen and phosphorus content, in order to draft a water and nutrient balance. The three different fertilization strategies did not produce any relevant effect on the final plant height and all plants were ranked in the top quality market category.The data confirmed that the use of CRFs could contribute to a huge reduction of nitrogen and phosphorus run-off in the environment and could be a winning strategy for the fertilization of HONS in the nitrate vulnerable zone.

INTRODUCTION

The production of Hardy Ornamental Nursery Stocks (HONS) is an important horticultural sector in several countries. In Europe, one of major HONS production area is located around the town of Pistoia (Tuscany, Italy); in this area, container cultivation has been increasingly used in the last 10-15 years as it provides many advantages, such as fast plant growth, year-round marketing and easy plantation establishment (Nicese and Ferrini, 2009).

In the nurseries around Pistoia, water and nutrients are often applied in excess and this produces water wastage and environmental pollution due to the leaching of fertilisers, mainly nitrogen and plant protection products (ARPAT, 2007). In container culture, some leaching is required to prevent salt accumulation in the substrate. The salinity of groundwater in the area of Pistoia is relatively low (electrical conductivity, EC, ranges from 0.4 to 0.6 dS m^{-1}) and this does not justify the large leaching fraction (LF = water leached/water applied) applied in most nurseries, which is as high as 35-50% (Marzialetti and Pardossi, 2003).

As a result of this concern, studies on the evaluation of leaching potential of various sources of N fertilizers is necessary to develop fertilizer programs aimed to minimize leaching losses. Many controlled-release fertilizers (CRFs) are coated soluble fertilizers which release the nutrients slowly over an extended duration so that nutrient release would coincide with the nutrient demand for crop growth, thereby minimizing potential leaching losses (Ben-Asher et al., 2005).

The aim of this research has been to compare the effects of the traditional fertigation versus new fertilization strategies, based on the use of controlled slow-release fertilizers (CRFs), on plant growth, nitrogen and phosphorus run-off in two container HONS species (*Photinia* x *fraseri* and *Prunus laurocerasus L.*).

MATERIALS AND METHODS

The experiment was carried out at the Centro Sperimentale per il Vivaismo (CE.SPE.VI.), located in Pistoia (Tuscany, Italy).

The selected crops red-tip photinia (*Photinia x fraseri)* and cherry laurel (*Prunus laurocerasus L.*) were transplanted on April 15th (2011) in plastic pots of Ø 24 cm, filled with a peat-pumice mix (1:1 v:v). The experimental period lasted 28 weeks, from April 20th until November 3rd; green pruning was carried out at the end of the 27th week (06/07/2011).

Three different fertilization strategies (Table1) were compared:

1) **CONTROL**: without CRF, characterized by continuous fertigation with Universol blue® (soluble fertilizer 18%N-11%P_2O_5-18%K_2O+2.5%MgO+microelements in trace) at 0.30 g/L. The pre-mentioned amount was raised up to 0.40 g/L at the end of week 36 (07/09/2011), in order to sustain the higher crop nutrient uptake in the last two months of cultivation;

2) **HI-END**: plants were fed with 6 g/L of Osmocote Exact® Hi-END (controlled-release fertilizer 15%N-8%P_2O_5-11%K_2O+2%MgO +microelements in trace, lasting 12-14 months), included into the substrate on April 20th;

3) **STANDARD [SOE]:** plants were fed with 4 g/L of Osmocote Exact® (controlled-release fertilizer 15%N-9%P_2O_5-11%K_2O+2%MgO +microelements in trace, lasting 8-9 months) blended into the substrate on April 20th; at the end of 36th week, an additional fertilization with 2 g/L of Top Dress®, (22%N-5%P_2O_5-6%K_2O+2%MgO +microelements in trace, lasting 4-5 months) was supplied by hand on the top of each pot.

In treatments 2 and 3 only acidified water (with sulphuric acid, in order to avoid nitrogen supply) was used for irrigation. Osmocote Exact and Hi-END®, Universol®,and Top DRESS®, are commercialized by Everris International B.V. (Waardenburg, The Netherlands).

In Pistoia nurseries, different species are often located in the same plot and usually irrigation is scheduled in accordance with the most demanding one in terms of water. In order to reproduce the commercial asset, we put in the same irrigation sector both species of the same treatment: irrigation was scheduled twice a day while irrigation volume has been set in order to obtain a LF of 20 % in photinia that has the biggest water need.

During the whole experimental period, climatic variables (relative humidity, air temperature, wind velocity, rain and global solar radiation) were measured by a climatic weather station installed at the CE.SPE.VI.

Every week plant height, cumulate irrigation and drainage volume were measured on four replicates for each treatment and species (36 photinia and 36 prunus plants for each replicate, with a 15 m^2 plot size). Every four weeks two average samples of drainage water and irrigation water for each treatment and species were analysed, determining total nitrogen and phosphorus content, in order to calculate a water and nutrient balance. Nitrate content was measured by a spectrophotometric method, using the salicylic-sulphuric acid procedure (Cataldo et al., 1975) while ammonium content was quantified spectrophotometrically through the indophenol method (Kempers and Kok, 1989); phosphate content was determined by spectrophotometer using the molybdenum blue method (Olsen and Sommers, 1982).

At the end of the experimental period, a commercial evaluation of 20 plants of the cultivated crops was performed by a panel of ornamental nursery growers. Leaf area index, leaf and stem dry weight (4 plants for each treatment) were measured at the end of the trial in order to determine the influence of the treatments on plant growth.

Data were elaborated in order to obtain the average and the standard error of each parameter measured or calculated. The influence of fertilization strategies on crop growth and water relations was assessed by means of ANOVA and LSD test performed with Statgraphics Plus 5.1 (Manugistic, Rockwille, USA).

RESULTS AND DISCUSSION

Plant growth

Growth analysis (Table 2) revealed that only SOE treatment produced in photinia, at the end of the growing period, a significant reduction of all growth parameters when compared to the continuously-fertirrigated treatment (control): leaf area index (LAI, -21%), leaf dry weight (LDW, -23%), stem dry weight (STW,-7%) and total shoot dry weight (TSDW,-14%). Hi-end treatment produced also in photinia plants a slight LDW reduction, but no significant differences were recorded on the TDW (total dry weight) in comparison with the control. This is due to the fact that a slight LDW reduction doesn’t affect much the TDW, mingling to the experimental error. On the contrary, fertilization strategies did not influence significantly the growth parameters in cherry laurel, with the only exception of a slight reduction of LAI, induced by the SOE treatment.

Growth analysis results highlighted that SOE treatment, in the growing conditions of the Pistoia area, is not suitable for plants characterized by a high growth ratio, such as photinia, since it reduced the plant growth. Osmocote 8-9 month standard used with this dose and with these environmental conditions was not able to sustain adequately plants nutrient needs, especially during July and August. The addition of the Top Dress fertilizer to the SOE treatment during September reduced (or cancelled) the nutrient deficiency, but anyway it has not been able to recover the lost dry matter: so, probably, in these conditions, the Top Dress fertilization must be anticipated to at the end of July, in order to satisfy the higher nutrient request of photinia crop.

In photinia, the reduction of the total leaf dry matter and the LAI, induced by the CRF treatments, also produced a significant reduction of crop evapotranspiration with respect to the Control (-8.1% as means of the CFR treatment compared to top control), while in cherry laurel no effect was recorded (Table 3).

Although in photinia fertilization strategies influenced significantly the growth parameters, all the plants were classified as top quality category by skilled nurserymen, since the three different fertilization methods did not influence the final plant height and quality (Fig. 1).

Water and nutrient balance

The leaching fraction was very different between the two species aside from the treatment applied: the average seasonal leaching fraction (mean of the three treatments) was of 16.3% and 42.1% respectively in photinia and cherry laurel (Table 4). This strong difference was due to the use of a common irrigation scheduling for both species that are quite different for evapotranspiration requirements: in fact, the average cumulated evapotranspiration during the whole growing period (197 days) was of 491.1 and 322.4 L m^{-2} for photinia and cherry laurel respectively.

The average seasonal nutrient concentration of nitrogen (reported as nitric, ammoniacal or total), phosphorus, in the drainage collected weekly from the different species and fertilization strategies are reported in Table 4. It appears that the content of selected nutrients in the drainage collected from CRF treatments was very low and almost the same to that revealed in the irrigation water (data no shown), while in the control treatments the same nutrients were from two until four times higher, especially for nitrate.

The presence of high nutrient concentrations in the control treatment drainage (in both tested crops) led to an high nutrient runoff, especially as regards nitrogen and, to a lesser extent phosphorous. In fact, the amount of nutrients leached as average of the two species was much higher in the control with respect to the CRF treatments, and it was not significantly different between the two CRF treatments. In the control, the nutrient runoff was higher in cherry laurel than in photinia: this is probably due the high leaching fraction produced by cherry laurel plants.

Moreover, since Osmocote Hi-End releases the 25% of nutrients at a later time, when blended in the substrate, allows avoiding the top dressing practice at the end of summer, with money and time save; this delayed release could also improve the shelf-life of the plants

CONCLUSIONS

The three different fertilization strategies did not produce any relevant effect on the final plant height and all plants were ranked in the top quality market category.

The content of selected nutrients in the drainage collected from CRF treatments was very low and almost the same to that revealed in the irrigation water, while in the control treatments the same nutrients were from two until four times higher, especially for nitrate.

The presence of high nutrient concentrations in the control treatment drainage (in both tested crops) led to an high nutrient runoff, especially as regards nitrogen and, to a lesser extent phosphorous.

The results obtained state that CRFs can contribute to a huge reduction of the nitrogen and phosphorus run-off with respect to continuous fertigation, representing a winning strategy for the HONS fertilization in the nitrate vulnerable zone.

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Tables

Table 1. Different fertilization strategies

Fertilization strategies	**Plant feeding method**
CONTROL	Continous fertigation with Universol blue® (30g/l up to 40 g/l)
HI-END	Osmocote Exact® Hi-END lasting 12-14 months (6 g/l)
SOE	Osmocote Exact®,lasting 8-9 months (4 g/l) + Top DRESS®, lasting 4-5 months (2 g/l)

Table 2. Effect of three different fertilization strategies (see the text for treatment description) on plant height, leaf area index (LAI), leaf and stem dry weight as determined at the end of growing season (November 3th,2011, 202 days from planting). Plant density was 2.4 plants m^{-2}.

Parameter	**Photinia**			**Prunus**		
	Control	**Hi-End**	**SOE**	**Control**	**Hi-End**	**SOE**
Plant height (m)	1.34 A[1]	1.32 A	1.29 A	0.79 A	0.78 A	0.76 A
Leaf Area Index (m^2/m^2)	2.83 A	2.34 B	2.24 B	2.57 A	2.33 AB	2.24 B
Leaves dry weight (kg/m^2)	0.43 A	0.36 B	0.33 C	0.34 A	0.31 A	0.33 A
Stems dry weight (kg/m^2)	0.56 A	0.55 A	0.52 A	0.30 A	0.28 A	0.28 A
Shoot dry weight (kg/m^2)	0.99 A	0.91 AB	0.85 B	0.64 A	0.59 A	0.61 A

[1] For each parameter and for each species, different letters indicate a significant difference among the treatments, according to LSD test (P<0.05, n=3).

Table 3. Effects of the three fertilization strategies on water balance (cumulated irrigation volume drainage and evapotranspiration) in *Photinia* and Cherry laurel shrubs. Means of weekly leaching fraction was also reported. Data are the means of two replicates.

	Photinia		**Prunus**		**Mean**	**Relative value**
			Water supply (L m^{-2})			
Control	593.8 A[1]	*100.0%*	547.0 A	*100.0%*	570.4 A	*100.0%*
Hi-End	571.0 A	*96.2%*	557.1 A	*101.8%*	564.1 A	*98.9%*
SOE	577.6 A	*97.3%*	544.8 A	*99.6%*	561.2 A	*98.4%*
			Water drainage (L m^{-2})			
Control	86.6 B	*100.0%*	229.7 A	*100.0%*	158.1 A	*100.0%*
Hi-End	87.2 B	*100.7%*	226.2 A	*98.5%*	156.7 A	*99.1%*
SOE	95.3 A	*110.1%*	225.8 A	*98.3%*	160.5 A	*101.5%*
			Leaching fraction %			
Control	15.5% B	*100.0%*	43.0% A	*100.0%*	29.3% A	*100.0%*
Hi-End	16.1% B	*103.8%*	41.1% A	*95.5%*	28.6% A	*97.7%*
SOE	17.2% A	*110.9%*	42.1% A	*97.7%*	29.6% A	*101.2%*

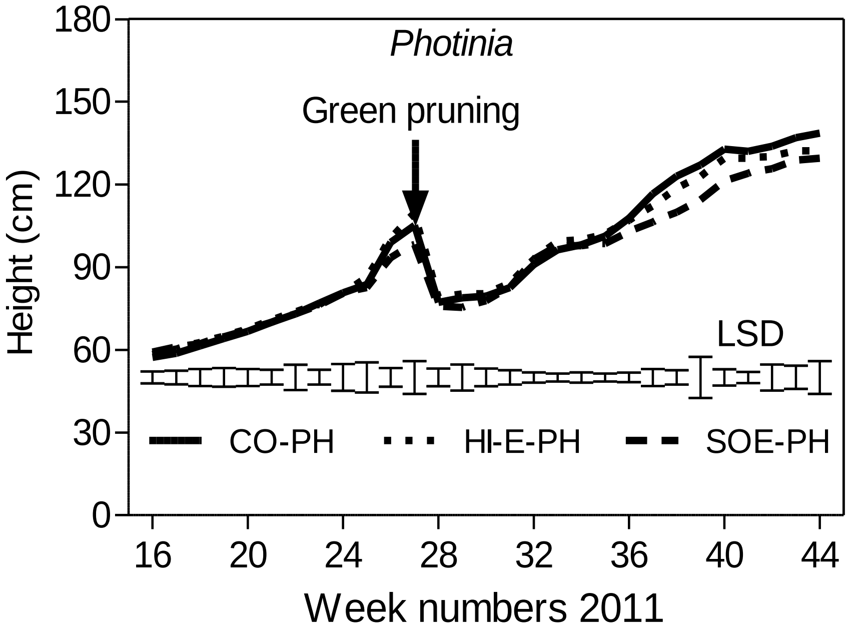
[1] For each species and parameter, different letters indicate a significant difference among the treatments, according to ANOVA and LSD test (P<0.05).

Table 4. Effects of the three fertilization strategies on the content of some nutrients ($N\text{-}NO_3$, $N\text{-}NH_4$, NTot, $P\text{-}PO_4$) in the drainage collected from pots of *Photinia* and cherry laurel.

	Photinia		**Prunus**		**Mean**	**Relative value**
Mean [$N\text{-}NO_3$] in drainage water						
Control	40.8 A	*100.0%*	37.3 A	*100.0%*	39.0 A	*100.0%*
Hi-End	8.7 B	*21.4%*	7.33 B	*19.7%*	8.0 B	*20.6%*
SOE	6.3 B	*15.4%*	6.0 B	*16.0%*	6.1 B	*15.7%*
Mean [$N\text{-}NH_4$] in drainage water						
Control	0.62 A	*100.0%*	0.60 A	*100.0%*	0.61 A	*100.0%*
Hi-End	0.63 A	*103.0%*	0.54 A	*89.8%*	0.59 A	*96.5%*
SOE	0.76 A	*123.2%*	0.66 A	*109.6%*	0.71 A	*116.5%*
Mean [Ntot] in drainage water						
Control	41.4 A	*100.0%*	37.9 A	*100.0%*	39.6 A	*100.0%*
Hi-End	9.4 B	*22.6%*	7.9 B	*20.8%*	8.6 B	*21.8%*
SOE	7.6 B	*18.3%*	6.8 B	*18.0%*	7.2 B	*18.1%*
Mean [$P\text{-}PO_4$] in drainage water						
Control	5.3 A	*100.0%*	7.6 A	*100.0%*	**6.5 A**	*100.0%*
Hi-End	1.9 B	*36.2%*	1.7 B	*22.5%*	**1.8 B**	*28.2%*
SOE	2.6 B	*47.7%*	3.0 B	*39.2%*	**2.8 B**	*42.7%*

[1] For each species and parameter, different letters indicate a significant difference among the treatments, according to ANOVA and LSD test ($P<0.05$).

Figures



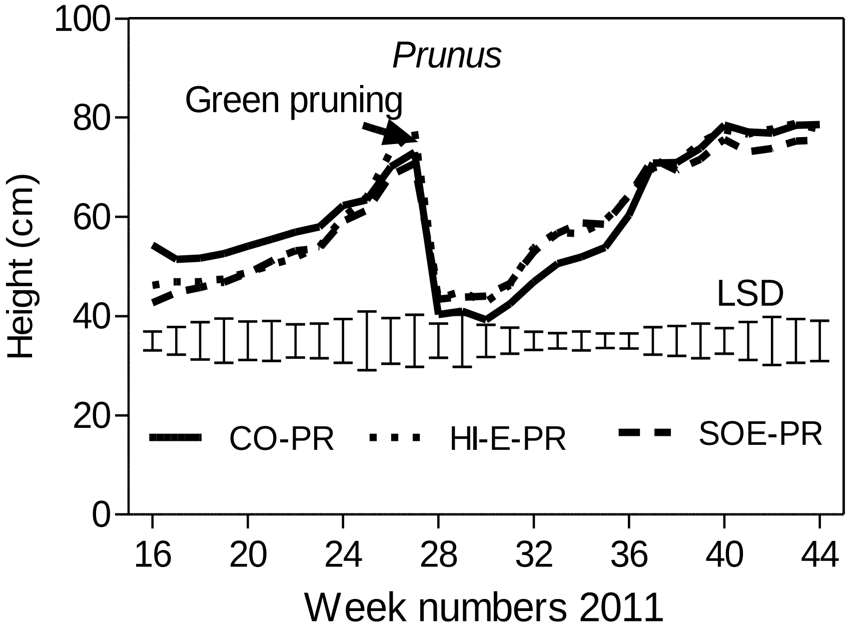


Fig. 1. Effect of three fertilization strategies (CO, continuous fertigation; HI-E, 6g per litre of substrate of Osmocote HI-END, 12-14 months of longevity; ST, only Osmocote standard, longevity of 8-9 months included in the substrate at 4g/L plus TOP DRESS 2g/L distributed on week 37) on the height of photinia and prunus plants during the 34 weeks of the experimental period. Data represent the average of four replicates (n=6). The LSD for each measurements (P<0.05) was also reported.