Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria (INIA)
Available online at www.inia.es/sjar
http://dx.doi.org/10.5424/sjar/2013113-3764

Spanish Journal of Agricultural Research 2013 11(3): 833-841
ISSN: 1695-971-X
eISSN: 2171-9292

Effect of different fertilization strategies on nitrogen balance in an outdoor potted crop of *Osteospermum ecklonis* (DC.) Norl. 'Purple Red' under Mediterranean climate conditions

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Abstract

Fertilization management and meteorological conditions can affect leachate composition and the balance of nitrogen (N) added during the cultivation of ornamentals. The main objectives of this study were to estimate the N balance components and to establish relationships between the N concentration in leachates and meteorological variables when different fertilization strategies are used in an outdoor potted crop of *Osteospermum ecklonis* (DC.) Norl. 'Purple Red'. Two fertilizations strategies, *i.e.* continuous fertigation (NS) and incorporated controlled-release fertilizer (CRF), were applied to the crop. The treatments were two NS doses (NO_3^--N concentration in each NS, NS-A: 154 mg L^{-1} and NS-B: 112 mg L^{-1}) and two CRF doses (CRF-C: 5.0 g L^{-1} of substrate and CRF-D: 2.5 g L^{-1} of substrate). The N loss by leaching was higher in the NS-A treatment than in the other ones (1.1 g pot^{-1}, 11% of total available N). The amount of N accumulated by the plants was higher in the NS treatments than in the CRF treatments (average 2.5 g pot^{-1}, 29.5% of total available N). However the efficiency of use of N was the greatest in the CRF-D treatment (23.9 g dry matter produced g^{-1} N supplied). About 50% of the total available N was measured in the substrate in all treatments (average 3.8 g pot^{-1}). The concentration of N in the leachates for the two CRF treatments did not correlate with the substrate temperature or precipitation. The N released from the CRF matched the nutritional requirements of the plants better than the N applied by continuous fertigation.

Additional key words: controlled-release fertilizer; fertigation; ornamentals; nitrate pollution; nitrogen efficiency.

Introduction

The subsector of potted ornamental plants occupies an important position in the agricultural production in Catalonia (northeast Spain) (MARM, 2010). According to a survey of the main producers in this subsector, different agricultural practices are used (irrigation and fertilization methods) depending on the kind of crop (Marfà *et al*., 2010). In general, nursery growers in Catalonia tend to apply controlled-release fertilizers (CRF) and use sprinkler irrigation systems when growing woody ornamental plants (Marfà *et al*., 2010), meanwhile fertigation with drips or microsprinkled is commonly used for fast-growing herbaceous plants. (Marfà *et al*., 2010).

Volume and composition of leachates is affected by fertilization and irrigation management (Bilderback, 2001). Nitrates from fertilizers are the dominant form of nitrogen (N) in leachates from crops (Cabrera, 1997; Fernández-Escobar *et al.,* 2004; Oliet *et al*., 2004; Narváez *et al*., 2012). Half of the nutrients and water applied has been described to be lost in potted shrubs production along the Mediterranean coast of Catalonia (Guérin *et al*., 2001). Meteorological conditions (*e.g.* temperature and precipitation) during the specific growing period and the plants' growth rate can also affect the concentration and quantity of nutrients lost through leaching (Seo *et al*., 2008). A negative correlation was observed between N concentration in leachates and the temperature (T) during the production of woody ornamental plants under fertigation (Narváez *et al*., 2012). When CRF prills are applied to the crop,

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Received: 18-11-12. Accepted: 15-07-13.

Abbreviations used: CRF (controlled-release fertilizer); EC (electrical conductivity); LF (leaching fraction); MCU (multi computer unit); MLRM (multiple linear regression models); NS (nutrient solution); PR (precipitation); T (temperature).

the release of nutrients contained in prills can be speeded up or delayed when compared with to the specifications of the CRF due to T or alterations in granule coating materials (Shaviv, 2001). If substrate T is over 21°C, the nutrients can be released more quickly than expected (Du *et al.,* 2008).The longevity of the CRF indicated by the manufacturer could then be considerably reduced as T increases (Huett & Gogel, 2000). A high rate of nutrient release from CRF can promote losses of soluble N by leaching (Million *et al*., 2010; Narváez *et al*., 2012). Depending on the fertilization method, variables such as precipitation (PR) and T take on special relevance on the pattern of nutrient leaching when growing potted plants outdoors in areas along the Mediterranean coast, such as Maresme County in Catalonia, which has moderate winter temperatures, very hot and dry summers, and rainy autumns (METEOCAT, 2012). T and PR are variables that are often used to predict the concentration of NO_3^- in leachates (Ramos & Martínez-Casanovas, 2010; van der Laan *et al*., 2010; Narváez *et al*., 2012).

Many cultural practices have been adopted by nursery growers to limit the loss of nutrients through leachates. If common agricultural practices are not fully effective or the leachates are not managed properly, dumping them into the surrounding environment can cause non-point source NO_3^--N pollution of the groundwater (OJ, 2000). Moreover, some nurseries in Catalonia are located in areas that are particularly vulnerable to NO_3^- contamination (Agència Catalana de l'Aigua, 2005). Research on N balance components and its relationship with meteorological variables in nursery crops along the Mediterranean coast can provide useful information to recommend agronomic practices to prevent or minimize the loss of nutrients by leaching and therefore minimize the environmental impact of NO_3^--N. The aims of this experiment were: i) to determine the effect of different fertilization strategies and doses on crop productivity and the composition of the leachates generated, ii) to determine N balance components for the different fertilization strategies and doses used, and iii) to establish relationships between N concentration in leachates and meteorological variables.

Material and methods

An experiment was carried out involving the two more common fertilization strategies used in nurseries from the coast of Catalonia (fertigation and incorporated CRF) for crops of ornamental plants (Marfà *et al*., 2010).

Plant material and growing conditions

The experiment was carried out in an outdoor plot at the IRTA research station in Cabrils, Catalonia (Spain) (41° 25' N, 2° 23' E, altitude of 85 m) from 10 May to 13 July 2010. Homogeneous rooted cuttings of *Osteospermum ecklonis* (DC.) Norl. 'Purple Red' were planted in 4-L pots placed at a distance of 40 cm from the other pots in all directions, thus resulting in a density of 6 plants m^{-2}. Sphagnum peat Pindstrup No. 5 (Pindstrup Moseburg SAE, Burgos, Spain) was the growing medium used, in accordance with the local practice of growing herbaceous ornamentals. At the beginning of the experiment, the NO_3^--N concentration in the substrate was 41.8 mg L^{-1}, the pH was 5.5, EC was 0.6 dS m^{-1} and the total Kjeldahl N content was 0.95%. An automatic irrigation system, MCU Ferti (Multi Computer Unit; FEMCO, Damazan, France), and a drip irrigation system (one drip emitter per pot, 2 L h^{-1}) were used. The irrigation was started automatically in each treatment using an automatic irrigation-control tray system for outdoor nurseries (Cáceres *et al*., 2007). The volume of irrigation water applied was periodically modified to provide a leaching fraction (LF: volume leached/volume applied * 100) about 20%. The same volume of irrigation water was applied in all treatments. The pH of the irrigation water was 7.3, the electrical conductivity (EC) was 1.2 dS m^{-1} and the NO_3^- concentration was 14.0 mg L^{-1}.

Fertilizer treatments

The experiment was arranged in a random design with four fertilization treatments, with 156 plants each (one plant per pot). In two of them, the fertilizer was applied in a nutrient solution (NS) by continuous fertigation. The NS was applied to the plants at two different doses (A and B). In the NS-A treatment, a relatively high-concentration NS was applied that had been previously assayed for other crops of outdoor ornamental pot plants (Marfà *et al*., 2002). The NS-B treatment dose had about 30% less N, P and potassium (K) than dose A (Table 1). In the growing media used in the other two treatments, a resin-coated Osmocote

Table 1. Average composition of nutrient solution formulations used in the fertigation treatments (NS-A and NS-B)

Treatments	NO_3^--N	NH_4^+-N	$H_2PO_4^-$	SO_4^{2-}	K^+	Ca^{2+}	Mg^{2+}	pH	EC
	(mg L^{-1})								(dS m^{-1})
NS-A	154	14.0	118	269	254	272	67.2	6.0	2.0
NS-B	112	0.0	78.4	298	168	272	67.2	6.0	1.7

Exact Standard (CRF) 16N (7.4 N-NO_3^- + 8.6 N-NH_4^+)-3.9P-10K with a 3- to 4-month release period at 21°C was applied (Scotts International B.V. Scotts Professional, Heerlen, Netherlands) at two different doses: 5.0 g L^{-1} and 2.5 g L^{-1} for treatments CRF-C and CRF-D, respectively. These doses applied cover the usual range of fertilizer rates in commercial production. In accordance with local practise, before the containers were filled with the growing medium, the CRF was homogeneously mixed with the substrate. The total amounts of N supplied by the fertilizer and irrigation water were 7.4 g pot^{-1}, 3.9 g pot^{-1}, 3.4 g pot^{-1} and 1.9 g pot^{-1} for the NS-A, NS-B, CRF-C and CRF-D treatments, respectively (Table 2).

Nitrogen balance: leachates, substrate and plant data collection

During the growing period, the volume of input water was measured daily in all treatments. The corresponding leachate volume and N concentration were also measured for each treatment. Lysimetric boxes were used to gather the leachates (Fare *et al*., 1994; Cáceres *et al.,* 2007), with three boxes per treatment (n = 3). Each box had four pots, and the leachate produced by four pots was considered to be a repetition. The following variables were measured on a weekly basis in triplicate in the irrigation water, input NS and leachates: the pH was determined with a selective ion analyser (model EA 920, Orion Research, Inc., Beverly, MA, USA), EC was measured using a Crison conductivity meter (model GLP 31, Crison Instruments S.A., Barcelona), NO_3^- concentration by ion chromatography (model 761 Compact IC, Metrohm AG, Herisau, Switzerland), and NH_4^+ concentration with an Orion selective electrode (model 95-12, Orion Res. Inc., Beverly, MA, USA).

Physicochemical, hydrological and N characterization of the substrate was conducted before and after the experiment. Substrate samples from the CRF-C and CRF-D treatments were analysed at the end of the experiment after manually removing the CRF prills (de Kreij, 2004). The NO_3^- concentration in the extract (1

Table 2. Nitrogen balance and total dry matter from an outdoor potted crop of *Osteospermum ecklonis* (DC.) Norl. 'Purple Red' receiving different doses of either a nutrient solution (NS-A or NS-B) or controlled-release fertilizer (CRF-C or CRF-D). Nitrogen is expressed as the relative amount of total N (%) (applied as fertilizer, in irrigation water and in the growing medium at planting), and as absolute N values (g pot^{-1})

	NS-A		NS-B		CRF-C		CRF-D	
	%	g pot^{-1}	%	g pot^{-1}	%	g pot^{-1}	%	g pot^{-1}
Nitrogen								
Total applied	100	10.2	100	6.7	100	6.2	100	4.7
Plant uptake	$29^{a(z)**}$	3.0	30^{a**}	2.0	21^{b**}	1.3	15^{b**}	0.7
Growing medium	50^{ns}	5.0	64^{ns}	4.3	49^{ns}	3.1	57^{ns}	2.6
Leachate	11^{a*}	1.1	6^{ba*}	0.4	5^{b*}	0.3	4^{b*}	0.2
Remaining in CRF	—	—	—	—	10^{ns}	0.6	20^{ns}	0.9
Not measured $^{(zz)}$	10^{ns}	1.1	0^{ns}	0.0	15^{ns}	0.9	4^{ns}	0.3
Supplied by the fertilizer and irrigation water	—	7.4	—	3.9	—	3.4	—	1.9
Total dry matter	—	81.0^{a}	—	59.1^{cb}	—	61.9^{b}	—	45.5^{c}

^{z} In each row, means not followed by the same letter are significantly different according to Tukey's test at $p \leq 0.05$ probability level. ** $p < 0.001$, * $p < 0.01$, ^{ns} $p > 0.05$. ^{zz} Gaseous N losses and net mineralization.

substrate: 1.5 deionized water, by volume, sample substrate using a 500 mL-cylinder and pressed at 10 g cm^{-2}) was measured by ion chromatography (model DX 120, Dionex Corporation, Sunnyvale, CA, USA). The total N concentration was determined using the Kjeldahl method.

Total N of the plant was determined using the Kjeldahl method and the dry weight of the plant was measured by drying the sample at 60°C for 48 h at the beginning (in 3 plants) and end of the experiment (in 3 plants per treatment).

The N remaining in the CRF prills at the end of the experiment (CRF-C and CRF-D treatments) was measured by taking a substrate sample for gravimetric analysis and removing any CRF prills. These prills were ground manually according to Narváez *et al*. (2012). Total N in the solution obtained was determined using the Kjeldahl method and the NO_3^- content was measured using the ion chromatography system described above. The information gathered was used to calculate the N balance using the following equation (Narváez *et al*., 2012):

$$N_T - \Delta N_P - N_S - N_L - N_O = N_{NM}$$

where N_T = N applied as fertilizer and in irrigation water and N in the growing medium at planting; ΔN_P = N change in plant; N_S = N in the growing medium at the end of the experiment; N_L = N recovered in leachate; N_O = N remaining in the CRF prills; N_{NM} = N not measured.

Nitrogen supplied by the fertilizer and irrigation water (NO_3^--N + NH_4^+-N) was used to calculate the efficiency of use of N by plants (g total dry matter produced / g N supplied).

Substrate temperature and precipitation

Substrate T was recorded continuously throughout the experiment using a Testo data logger (model 177, Testo AG, Lenzkirch, Germany). Two sensors were placed in the pot in the CRF-C and CRF-D treatments. Substrate T data were used to define the variable H_{T21}, *i.e.* the accumulated degree hours per week for a base substrate T from 21°C (Narváez *et al*., 2012). Rainfall data were obtained from a meteorological station belonging to the Meteorological Network of Catalonia (METEOCAT) located at the IRTA experimental station. Precipitation (PR) has been used as a variable in several studies that model nitrate leaching (van der Laan *et al.,* 2010; Narváez *et al*., 2012).

Statistical analysis

All statistical analyses were performed using SAS v.9.1 (SAS Institute, Cary, NC, USA). All the sample data were analysed using one-way analysis of variance and mean separation among treatments was obtained by Tukey's test. Data on PR and substrate T (independent variables) from each CRF treatment were analysed using multiple linear regression models (MLRM, REG procedure in SAS software) for predicting the N concentration in leachates (dependent variable). For the MLRM, it was assumed that independent and dependent variables were random variables with a normal distribution. The general form of the MLRM was:

$$Y = A + \beta_1 \, PR + \beta_2 \, H_{T21}$$

where Y = nitrogen concentration in leachates (NO_3^--N + NH_4^+- N, in mg L^{-1}); A = intercept or independent term coefficient; PR = precipitation (L m^{-2} $week^{-1}$); H_{T21} =accumulated degree hours per week for a base substrate T from 21°C (°C h $week^{-1}$); β_1, β_2= regression parameters for PR and H_{T21} variables, respectively.

Results

Nitrogen, EC and pH in the leachates

Nitrate was the predominant form of N in the leachates from all treatments. It represented between 98% and 100% in both NS treatments, and between 73% and 97% during the first 6 weeks and 100% during the last 2 weeks of the growing period in both CRF treatments. Generally, N leaching in all treatments tended to decrease throughout the growing period (Fig. 1). The average N concentration was 77.0 mg L^{-1} for the NS-A treatment, 34.9 mg L^{-1} for the NS-B treatment, 38.1 mg L^{-1} for the CRF-C treatment and 16.8 mg L^{-1} for the CRF-D treatment (Fig. 1). Regardless of the fertilization strategy, these concentrations were relatively proportional to the total amount of N supplied by each treatment and irrigation water. In both NS treatments, the NO_3^--N concentration in the leachates did not exceed that supplied by the NS

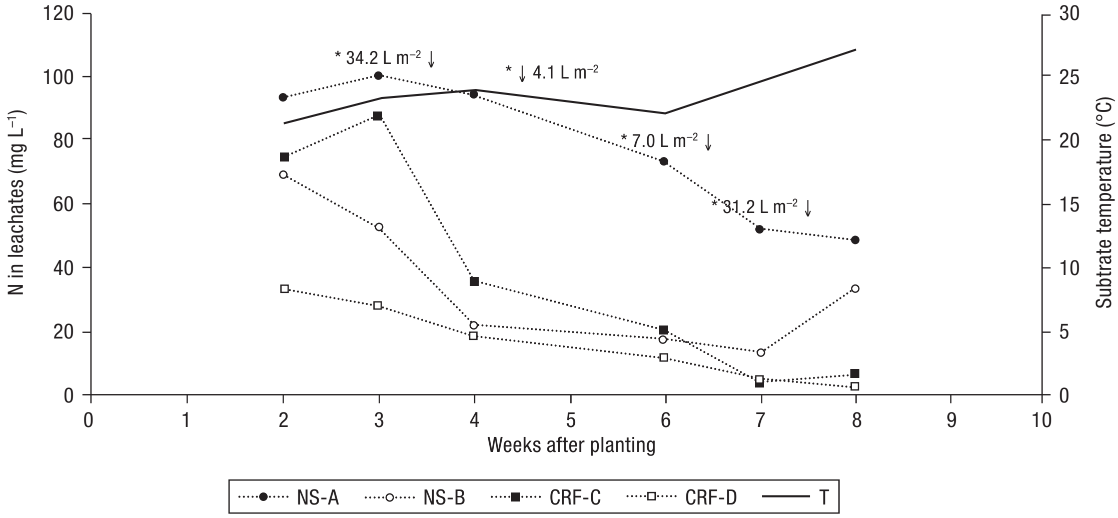

Figure 1. Daily N concentration (....) in leachates, averaged weekly, of outdoor-grown *Osteospermum ecklonis* (DC.) Norl. 'Purple Red' in 4-L containers receiving different doses of either a nutrient solution (NS-A or NS-B) or controlled-release fertilizer (CRF-C or CRF-D). On the secondary axis, average substrate temperature (T) over time. (*) Rainfall events.

(Table 1). The amount of N accumulated in the leachates showed a similar pattern based on the amount of N supplied by each fertilization mode (Fig. 2). Between weeks 3-4 and 7-8 of the growing period, two rainfall events took place that were more intense than those occurring in weeks 4-5 and 6-7 and this resulted in an increase of up to 50% in the LF (Fig. 2). For this reason, for the periods described, an increase was observed in the quantity of N leached (Fig. 2). Therefore, during weeks 3-4, an abrupt increase occurred in the amount of N leached from all the pots, these amounts being the highest in those receiving the treatment NS-A (Fig. 2). However, during weeks 7-8, at the end of the growing period, this increase was only observable with NS (Fig. 2).

The pattern observed for the EC values in the leachates was similar for treatments within each fertilization method (NS or CRF); EC were not related to N concentration in the leachates. During the growing period, EC tended to increase progressively when the

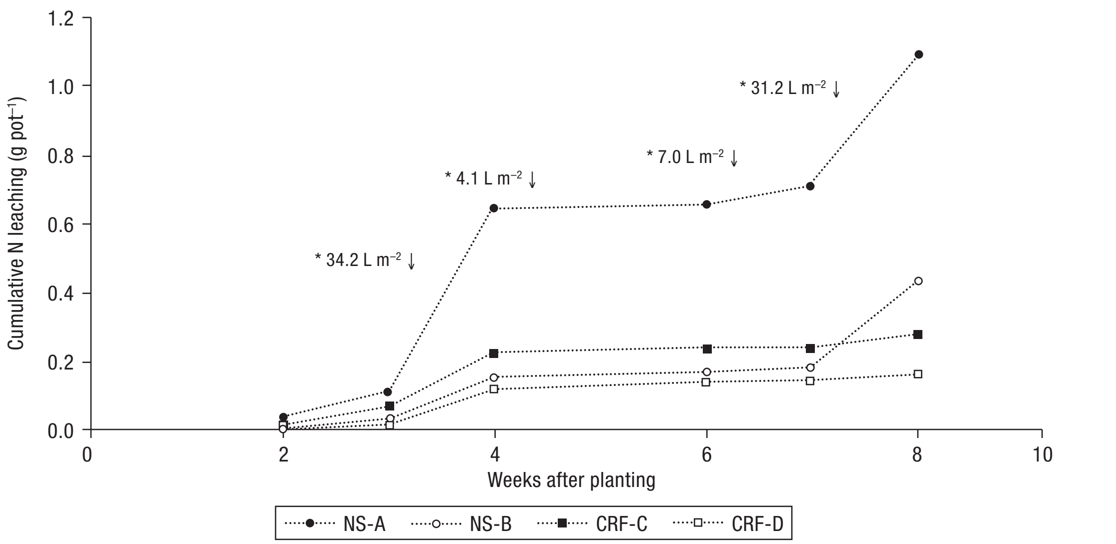

Figure 2. Cumulative nitrogen leaching-loss (NO_3^--N + NH_4^+-N) of outdoor-grown *Osteospermum ecklonis* (DC.) Norl. 'Purple Red' in 4-L containers receiving different doses of either a nutrient solution (NS-A or NS-B) or controlled-release fertilizer (CRF-C or CRF-D). (*) Rainfall events.

Table 3. Multiple linear regression equations for the prediction of the N concentration in leachates (Y, nitrogen leaching; mg L^{-1}) related to the weekly cumulative degree hour up to 21°C (H_{T21}; °C h $week^{-1}$) and precipitation (PR; L m^{-2} $week^{-1}$) for a potted crop of *Osteospermum ecklonis* (DC.) Norl. 'Purple Red' ($Y = A + \beta_1\ PR + \beta_2\ H_{T21}$) receiving different doses of controlled-release fertilizer (CRF-C or CRF-D)

Treatments	Regression parameters	Value	*p*-value	R^2	F-value	*p*-value
CRF-C	A	75.5	0.1413	0.34	2.13	0.1903
	β_1	–4.1	0.4405			
	β_2	–0.04	0.5110			
CRF-D	A	51.2	0.3178			
	β_1	–2.4	0.6657			
	β_2	–0.04	0.4887			

NS was used (average EC: 1.6 dS m^{-1} for the NS-A treatment and 1.2 dS m^{-1} for the NS-B treatment) and was relatively stable when the CRF was applied (1.0 dS m^1 for the CRF-C treatment and 0.8 dS m^1 for the CRF-D treatment). The pH of the leachates showed a different pattern depending on the fertilization strategy used (NS or CRF). In the first four weeks of the growing period, the pH of the leachates was higher when the NS was applied (average pH: 6.5) than when the CRF was applied (average pH: 5.4). But after week four until the end of the growing period, the pH of the leachates from all the treatments converged on a value of 7.9 (data not shown).

Nitrogen leaching and its relationship to H_{T21} and PR

The average substrate T was moderate during the growing period. It remained below 24°C during the first 6 weeks and then rose to 27°C in the last week of the growing period (Fig. 1). Rainfall events recorded during the experiment were not intense (Fig. 1). The MLRM showed that there was not any significant relationship between the N concentration in leachates from the CRF treatments and the variables PR and H_{T21} (Table 3).

Nitrogen balance

Table 2 shows that the amount of N accumulated by the plants expressed as a % of total available N (N_T = N applied as fertilizer + N in irrigation water + N in the growing medium at planting) was significantly higher in the NS treatments than in the CRF treatments. There were no significant differences between the four treatments in terms of the amount of N accumulated in the substrate at the end of the experiment. The relative amount of N leached (% of total available N) corresponding to the NS treatments was significantly greater than that of the CRF treatments. The N remaining in the CRF prills at the end of the experiment was similar in both CRF treatments. There were no significant differences between the four treatments in terms of the amount of N not measured.

Nitrogen efficiency

The efficiency of use of N supplied by the fertilizer and irrigation water (g total dry matter produced/g N supplied) was 11.0 g g^{-1} for the NS-A treatment, 15.6 g g^{-1} for the NS-B treatment, 18.2 g g^{-1} for the CRF-C treatment and 23.9 g g^{-1} for the CRF-D treatment (Table 2). Thus, the CRF-D treatment was significantly the most efficient and the NS-A treatment was the least efficient in terms of the use of N for dry-weight production. Nitrogen efficiency was not significantly different between the NS-B and CRF-C treatments

Discussion

The presence of N in the form of NO_3^--N in leachates predominated compared to the form of NH_4^+-N, regardless of the quantity of N supplied and the fertilization method. This fact has been reported by several authors when growing potted plants, as a consequence of nitrification processes that actively occur in the substrate (Cabrera, 1997; Fernández-Escobar *et al*., 2004; Merhaut *et al*., 2006; Medina *et* *al*., 2008; Narváez *et al*., 2012). The N concentration in leachates is relatively proportional to the quantity of N supplied by each fertilization method, and there is a decreasing trend during the growing period (Fig. 1). Nevertheless, the general fertilization method (NS or CRF) do not seem to imply clear effect on the leachate N concentration. However, in a similar study on cultivation of a woody ornamental plant that lasted 7 months, it was observed that the N concentration in leachates and their trend were more influenced by the fertilization method (NS or CRF) than by the quantity of N supplied with each method (Narváez *et al*., 2012). The highest N concentrations in leachates were observed during the first weeks of the growing period (Fig. 1). The possible accumulation in the substrate of N not uptaken by the plants, combined with the increase in the LF caused by rain in early stages of the growing period, could explain the increase in N concentrations in the leachates (Fig. 1) and the quantity of N leached (Fig. 2). However, with NS (NS-A or NS-B), neither the concentration of N nor the EC of the leachates exceeded the concentration of N supplied or the EC level of the applied nutrient solution (Table 1). For the application of the CRF, the EC of the leachates from the plants was not higher than the EC of the irrigation water (1.2 dS m^{-1}). As mentioned above, the lack of correlation between the EC of the leachates and the concentration of N in the leachates contrasted with the observations of other authors who carried out similar studies (Merhaut *et al*., 2006; Narváez *et al*., 2012). In our experiment, the lack of correlation between N concentration and EC could indicate a better fit between the N supplied by each fertilization method and the nutritional requirements of the plants. Plant growth rate increased with increased substrate T (Fig. 1), which can result in an increased water requirement (Alarcón, 2002). To avoid the resulting increase in EC in leachates, it could be recommendable to reduce the salt concentration of the NS. At least during the first 4 weeks of the growing period, the leachates from CRF treatments were more acidic than both, irrigation water (7.3) and leachates of NS treatments (6.5). Among other factors, the type of substrate and the formulation and dose of N supplied to the crop can affect the nitrification of the substrate, which lowers the pH of the water solution in the root zone (Nimiera & Wright, 1986; Lang & Elliott, 1991; Merhaut *et al*., 2006).

Nitrogen concentration in the leachates of the plants fertilized with CRF was not related to PR and H_{T21} (Table 3). The PR and T of the substrate during this study were lower than those in a similar study in the same location that showed a positive relationship between these meteorological variables and the N concentration in the leachates after the application of CRF (Narváez *et al*., 2012). Rainfall and T would explain good fit between the release of N contained in the CRF and the uptake of N by the plants, in contrast to the mentioned previous experiment.

The quantity of N absorbed by the plants was significantly greater with NS than with CRF (Table 2). However, in similar studies, the application of higher quantities of N through the NS or CRF than those we have applied did not result in a higher amount of N absorbed by plants (Cabrera, 2003; Narváez *et al*., 2012). In other studies carried out with ornamental woody plants, around 0.1 g of N was taken up by the plant per month (Guérin *et al*., 2001; Narváez *et al*., 2012). In our study, this rate ranged from 1.5 g of N when the NS-A treatment was applied and 0.4 g of N when the CRF-D treatment was applied (Table 2). These results show that the type of plant and its growth rate (faster in short-cycle herbaceous ornamental plants than in medium- and long-cycle woody plants), the meteorological conditions during the growing period and the fertilization strategy can result in very different N uptake rates by plants. This uptake is not necessarily increased with increased N availability in the growing media (Narváez *et al*., 2012). Regardless of the fertilization strategy, more than half of the total N available to the crop can be retained in the substrate (Table 2). These relative quantities are greater than or equal to those reported by other authors who carried out studies under similar conditions (Cabrera, 2003; Ristvey *et al*., 2004; Narváez *et al*., 2012). In our study, N probably accumulated in the substrate solution due to the characteristics of the substrate. The quantity of N lost through leaching was relatively low when compared with the quantities detected in similar studies in which more than 50% of applied N was lost (Guérin *et al*., 2000; Cabrera, 2003; Marfà *et al*., 2006; Narváez *et al*., 2012). The high quantities of N absorbed by the plants and accumulated in the substrate, combined with mild rainfall, could explain why relatively little N was lost through leaching in our study compared to others.

The quantity of N remaining in the CRF prills at the end of the growing period was similar to the quantity detected by other authors when applying CRF to plants with similar life spans under conditions of constant T between 20°C and 22°C (Hershey & Paul, 1982; Niemiera & Leda, 1993). The T stability during most of the growing period (mean T of 22.7°C with little variation during the first 6 weeks) (Fig. 1) did not cause accelerated release of the N in the CRF prills (Narváez *et al*., 2012). The amount of N not measured in the N balance was not affected by the fertilization strategy and the relative quantities (Table 2) were lower than those reported by other authors. This is mainly attributed to the process of denitrification and/or NH_3 volatilization (Niemiera & Leda, 1993; Cabrera, 2003). As mentioned above, the rate of N uptake by the plants per time unit was greater with increased N rates (NS-A treatment); however, the efficiency of the use of N was greater in the plants that received less N (CRF-D treatment) when compared with other treatments. Although the plants that received the NS-A treatment had a higher growth rate because they had more nutrients available than NS-B treatment, they also lost more N through leaching. This contributes to explain the lower efficiency in N use when compared with other treatments. The loss of N through leaching, which was favoured in some cases by rainfall, irrigation or fertilization management, could explain why the efficiency in N use by plants was not always increased with increased N rates (Narváez *et al*., 2012). The better fit between the release of N from prills and the plants nutritional requirements in CRF treatments, resulted in a more efficient use of N by plants than when NS was applied through fertigation. Although plants with NS had a higher growth rate compared to the plants that received CRF, they did not use the N as efficiently and lost more N through leaching. These results, combined with the gradual increase in the EC of the leachates, reflect the need to adjust the composition of the NS during the growing period to prevent excess supply of N to plants in specific growing stages.

Based on these results and those obtained with woody ornamental plants (Narváez *et al*., 2012) some practical recommendations on fertilization of ornamental crops grown in containers in Mediterranean coastal areas can be done. Taking into account the meteorological characteristics of this region, it would be better to apply CRF to slow-growing crops such as woody ornamentals at programmed doses instead of making one application at the beginning of the growing period. This would prevent the major losses of N through leaching. In the case of applying a NS to plants, it is necessary to change the concentration of the NS depending on plant stage to reduce the accumulation of salts in the substrate and their loss through leaching. Reducing the EC of the NS with increasing crop's evapotranspiration is also recommended.

Acknowledgements

We would like to express our appreciation for the financial aid received from the National Institute for Agriculture and Food Research and Technology (INIA) within the framework of projects RTA2007-00034-00-00 and RTA2010-00112-00-00 and the predoctoral grant received by Lola Narváez from the INIA.

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