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Seasonal Biomass and Nitrogen Accumulation of *Rosa* 'Mariandel®' Grown in Compost Amended Peat at Different Fertilization Rates[1]

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Abstract

The growth and nitrogen (N) uptake of *Rosa* 'Mariandel®' were evaluated at four fertilization rates: 0, 0.4, 0.8 and 1.2 g N/liter (0, 0.016, 0.032 and 0.048 oz/qt). Plants were harvested at 6-week intervals. New shoots in all treatments retained the highest relative dry weight percentage, apparently at the expense of root. The total N concentration, content, and uptake at 12 and 18 weeks, but not at 6 weeks, after potting were significantly ($r^2 > 0.59$; $P = 0.0005$) affected by rates of fertilization. Although DM in the old shoots of all treatments slightly increased over the first 6 weeks, the corresponding N content decreased due to translocation. Except in old shoots, a significant linear trend occurred between DM accumulation and N content but not with N concentration (at least up to 12 weeks). However, N concentration in most plant parts was significantly ($P < 0.05$) correlated with the respective N content. Excluding N released from the substrate, plants in 0.4, 0.8 and 1.2 g N/liter treated pots received 80, 126 and 182 mg (0.003, 0.004 and 0.006 oz) N per week, respectively, as used Osmocote (15N–4P–7.5K–1.8Mg) showed a linear ($r^2 > 0.99$) N-releasing rate. The corresponding total mineralized N in each control pot was 96 mg (0.003 oz) and 140 mg (0.005 oz) over the first and the second 6-week interval. Overall, 'Mariandel®' grown in 0.8 and 1.2 g N/liter treated pots had the highest mean N concentration and content respectively.

Index words: N concentration, Osmocote, relative dry weight.

Significance to the Nursery Industry

Applying fertilizer based on the plant nutrient demand increases fertilizer use efficiency and thereby reduces environmental hazard. The plant nutrient demand can be determined by growing plants at various fertilization rates, harvesting the biomass and analyzing the respective nutrient contents at regular intervals. In this research, we investigated the N uptake of *Rosa* 'Mariandel®' with respect to its developmental stages and fertilization rates. This helps growers to match the time of fertilization with the active period for uptake. Apart from the current uptake, the early N demand of our test crop was fulfilled partly by N stored from the previous year. Consequently, the net dry matter production, N concentration, content, and uptake in fertilized and control (0 g N/liter) plants were nearly similar 6 weeks after potting. Such considered parameters were, however, affected by fertilization rates at 12 and 18 weeks after potting. Our results also suggested that the N supplied by compost was sufficient to support good plant growth in the control treatment until week 6. This revealed that, at least in potting media containing compost, time of fertilization is important to increase N recovery efficiency by reducing leached N. The following alternatives are thus advised for nurseries when compost is included in the substrate: (a) fertilizer should be applied at the latest 6 weeks after potting if fertilization coupled with irrigation (i.e. fertigation); (b) controlled release fertilizer with low initial N releasing profile might be preferred over Osmocote exact standard that releases its content constantly (such as the one used in this study).

Introduction

Organic materials like compost contain substantial amounts of essential nutrients (2, 8) although the content of mineral N (12) is inadequate to maximize the growth of containerized plants. Composts, however, can partly or completely substitute for traditional amendments of dolomitic limestone, micronutrients and some macronutrients (12). Thus, the fertilization schedule in the nursery should consider the availability of nutrients in potting media especially when composts are included. This is because maintaining high fertility levels in the substrates beyond the plant nutrient uptake potential can lower plant quality (14). Moreover, such nursery management practices are now regarded as a threat to ground and/or surface water quality (4). Apart from the rates of fertilization, the types of fertilizer are also known to influence the release of nutrients and their concentrations in the runoff water (17).

Many reports in the literature (5, 9, 14, 17, 20) have confirmed that the growth and biomass accumulation of nursery plants are influenced by the fertilization regime. Applying any fertilizer source in accordance with the nutrient requirement of the nursery crop is thus crucial to increase plant productivity and thereby the fertilizer use efficiency. However, the use of controlled release fertilizer (CRF) might have advantages over soluble fertilizers (4) if the nutrient releasing profile of CRF is matched correctly with the plant nutrient demand (13, 20). Plant nutrient demand can therefore be determined by growing plants at various fertilizer rates, harvesting at regular intervals, quantifying the dry weights and nutrient contents of different plant tissues (5, 13). Studying nutrient uptake and partitioning in different plant parts also provides an insight into the ability of plants (especially woody crops) to translocate and/or retranslocate accumulated nutrient reserves as these processes play an important role in ful-

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filling nutrient requirement for the growth of newly emerging plant parts (15, 18). The objective of this experiment was, therefore, to monitor biomass growth, N accumulation and partitioning of potted rose plants grown in compost amended peat medium under different fertilization regimes.

Materials and Methods

Experimental design. This study was conducted in a randomized complete block design (RCBD) with four replications at container experimental plots of the Woody Plant Science Section, Hannover, Germany. The planting stock was an improved *Rosa* 'Mariandel®' grafted onto wild *Rosa canina*. The age of the planting stock was 2 years. They were planted in 4 liter (#1) plastic pots containing 60% white peat and 40% substrate-compost (v/v) medium that was fertilized initially with CRF (Osmocote; 15N–4P–7.5K–1.8Mg, 5–6 month longevity, Scotts, Nordhorn, Germany) at the rate of 0, 2.67, 5.34 or 8.1 g/liter (0, 0.11, 0.22 or 0.33 oz/qt). This corresponded to the addition of N at 0, 0.4, 0.8 or 1.2 g/liter (0, 0.016, 0.032 or 0.048 oz/qt). The substrate-compost used in this study was derived from bio- and green-wastes and graded as 'type I' according to quality regulation for composts in Germany (19). Bio-waste refers to waste from domestic uses. Because of prolonged cold weather conditions, plants were kept in a glasshouse for the first 3 weeks. Throughout the experimental period (April to August 2006), all plants in a given treatment were irrigated equally when the water tension reached 100 hPa.

Data collection and laboratory analysis. Initial nutrient contents of the substrate such as total N (Vario MAX CN analyzer; Elementar, Hanau, Germany), and NH_4-N and NO_3-N (Autoanalyzer; Alpkem Corporation, Oregon, USA) were analyzed from 3 representative samples. The N concentration in old shoots and roots were similarly quantified from 10 randomly selected plants by severing them just below the grafting point. The respective fresh and dry weights were also determined before and after oven drying at 70C (158F) for 72 hrs.

Measurements from plants, substrates, and fertilizer were taken every 6 weeks until 18 weeks after potting. At each harvest, 2 plants from each replication were sampled randomly and partitioned into new shoots, old shoots, roots and flowers (if any). The corresponding fresh and dry weights were determined as described above. Identical plant parts that were sampled from the same treatment and replication were then mixed and milled to pass a 0.2 mm (0.0008 in) sieve screen (ISO 9001; Retschmühle, Germany). From each sample, two sub-samples were taken and subjected to total N analysis. The total number of flowers and new shoots were also counted. The number of flowers represents the sum of buds, half-opened, fully-opened and senile flowers.

Substrates in two pots of the same treatment were mixed thoroughly after recovering all visible fine roots. Four composite samples were taken immediately for volume weight determination (23). Based on the mean volume weight (g/cm^3), two composite samples [each equivalent to a wet weight of 150 g (5.29 oz)) were taken and CRF granules in one of these samples were removed (CRF–). In contrast, all granules were crushed inside the second sample (CRF+). Both samples were then shaken for 1 hr with 0.6 liter (0.53 qt) of 0.05 M $CaCl_2$ solution and analyzed for NH_4-N and NO_3-N. Moreover, initial K and P contents of the medium used were determined by atomic absorption spectrometer (AAnalyst 100/300, The Perkin-Elmer Corporation, USA) and photometry (Carl Zeiss, Germany) respectively. The electrical conductivity (EC) was determined by EN 13038 (6).

Calculations and statistical analysis. Relative dry weights of new shoots, old shoots, flowers and roots expressed as the percentage of dry weight of each plant part to the total plant dry weight. Thus, the product of relative dry weight in a given plant part and total dry weight represents the respective dry weight in that plant portion. The amount of N contained in each plant part was calculated by multiplying the concentration with its respective dry weight. Therefore, the sum of N content in all plant parts was considered to be the total N content in the whole plant at a given sampling time. Nutrient partitioned to each plant part over a given time interval was calculated as the difference between the tissues' previous and current mineral nutrient content. Nitrogen uptake by the plant over 6 weeks was calculated as the difference of total N content between the current and previous samplings. The amount of N_{min} remaining in the CRF was computed by subtracting N_{min} in (CRF–) from (CRF+). Thus, N_{min} in (CRF–) was considered to be N_{min} in the substrate solution at a given sampling time. All N increments in plants of unfertilized treatment were regarded as the contribution of substrate-compost assuming peat is a stable medium (3).

Analysis of Variance (ANOVA) was carried out for some selected parameters using the General Linear Model procedure of Statistical Analysis System (SAS Inst., Inc. 9.1 for Windows, Cary, NC). The Pearson correlation coefficient between two parameters was determined by simple linear regression analysis. For those parameters that showed poor linear correlation, the quadratic model was employed to improve the coefficient of determination (r^2). However, no significant improvement was observed and thus these results are not included in this paper.

Results and Discussion

Planting stock and substrate at potting. The mean total number of old shoots per planting stock was 5.7 ± 0.2 with the respective average length and diameter of 13.4 ± 0.7 cm (5.3 in) and 10.6 ± 1.1 mm (0.42 in). Based on the number of old shoots, all planting materials graded as 'high quality' (11). Mean total dry weight of initially sampled stocks was 37.7 ± 0.6 g (1.33 oz) with a diameter size of 22.1 ± 1.9 mm (0.87 in) at the base of grafting point. The relative dry weight of root, which is the relationship of root dry weight [17.6 ± 0.7 g (0.62 oz)] to total dry weight, was 46.7%. The remaining parts that correspond to 53.3% of total dry weight were considered to be old shoots. The average initial shoot-to-root ratio was 1.14 ± 0.11.

The substrate alone had initial P and K contents of 0.3 and 1.4 g (0.011 and 0.05 oz) per pot, respectively, which is even higher than the corresponding total uptake in 1.2 g/liter (0.048 oz/qt) treated plants (data not shown) suggesting that P and K (unless leached or fixed by the substrate surface) might be sufficient for optimal 'Mariandel®' growth. Thus, most of the results discussed here will be with special reference to N. Total N in the substrate at the time of potting was 0.83% with the N_{min} content being 197.5 mg/liter (0.008 oz/qt). Since matured composts can serve as slow release fertilizers (12) and are excellent sources of macro- (2) and micro-nutrients (8), the potential of substrate-compost to supply N was tested

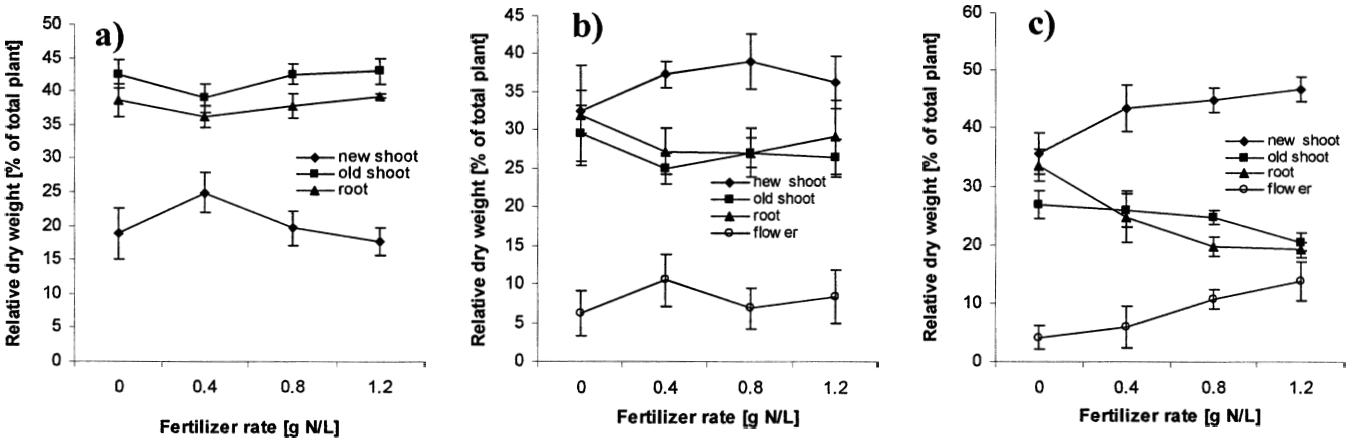

Fig. 1. Relative dry weight of different parts of *Rosa* 'Mariandel®' as affected by fertilization rates after: a) 6 weeks; b) 12 weeks; and c) 18 weeks from potting. Plants were fertilized with Osmocote (15N–4P–7.5K–1.8Mg) at N rate of 0, 0.4, 0.8 or 1.2 g N/liter (0, 0.016, 0.032 or 0.048 oz/qt). Vertical bars represent ± SE (n = 4).

by including the control treatment (i.e., zero Osmocote). The total amount of N that could potentially be available for the control plant was, therefore, 9.54 g (0.34 oz) N/pot when the dry potting density [288 g/liter (11.54 oz/qt)] was multiplied by the respective N concentration (0.83%) and volume of substrate [4 liter (3.52 qt)]. This, however, does not mean that all N from compost will be released within a relatively short time (i.e., at least over 18 weeks) as was confirmed by the low N_{min} recovered in the substrate (Fig. 3b), and poor increase in total N in the whole plant (Table 3) as well as individual part (Fig. 2).

Number of new shoots and flowers. New shoots were observed two weeks after potting in the control and 0.4 g N/ treatments as opposed to plants grown with 0.8 and 1.2 g N/ liter, which were delayed by 5 to 7 days. However, the final mean number of new shoots was unaffected by fertilization rates (18 ± 1). A delayed flushing of new shoots in the 0.8 or 1.2 g N/liter compared to control might be attributed to high EC resulting from the higher fertilization in addition to the high initial EC (4.3 dS/m) in the substrate. Khattabe (10) examined the response of *Rosa* species and cultivars to EC with most species being sensitive to EC; 50–100 mM sodium chloride.

Although flowering started early in the control plants, the mean flower number after 12 weeks varied between treatments from 8.5 (control) to 15.3 (0.4 g N/liter). Osmocote supplied at the rates of 0.8 and 1.2 g N/liter, however, resulted in plants with equal numbers of flowers (10.4). After 18 weeks, plants in the control treatment had the least total number of flowers (9.0), whereas plants grown with 1.2 g N/ liter had the highest (18.8). Total numbers of flowers during this period were 14.5 and 15.7, respectively, for 0.4 and 0.8 g N/liter treated plants. Flowers in the control treatment were small with few petal layers compared to plants in fertilized pots.

Relative dry weights of different plant parts. Plant growth parameters such as height, shoot diameter, fresh and dry mass production can be affected by rates of fertilization (5, 9, 13, 14, 20). In our study, the relative dry matter (DM) percentage of new shoots increased with fertilization rates particularly at the expense of roots (Fig. 1b and c). The relative dry weight of flowers during the third sampling was also enhanced by increasing N input while the percentage of old shoots declined. Larimer and Struve (13) observed that relative stem dry weights of both stress-tolerator (red oak) and competitor (red maple) species increased with increased fertigation levels but the reverse happened for roots with little change in the leaves.

Total dry matter production. Osmocote at the rate of 0.4 g N/liter (0.016 oz/qt) maximized total dry weight to 57.9 g (i.e., an increment of 20.2 g/plant) after 6 weeks as compared to others that only increased by ≈12 g/plant (Table 1). The larger part of this newly produced DM (83 to 89%) was partitioned to new shoots (Fig. 1a). Although the total dry weight after 12 weeks showed a wide range from 86.1 g (3.04 oz) for the control to 104.3 g (3.68 oz) for 0.4 g N/liter, the DM increment for all treatments was greater than 35 g/plant with the maximum increment at 1.2 g N/liter. Similarly, the DM increment between 12 and 18 weeks was 39.8, 43.3, 49.7 and 61.8 g (1.4, 1.5, 1.8 and 2.2 oz) per plant for Osmocote supplied at 0, 2.67, 5.34 and 8.01 g/liter (0, 0.11, 0.22 and 0.33 oz/qt) respectively (Table 1). These results show that DM production was affected strongly ($r^2 \leq 0.41$; $P \geq 0.008$) by fertilization in the later sampling as compared to

Table 1. Total dry weight (g/plant) and shoot-to-root ratio of 'Mariandel®' grown in 40% compost amended peat medium fertilized with Osmocote (15N–4P–7.5K–1.8Mg) at N rate of 0, 0.4, 0.8 or 1.2 g/liter (0, 0.016, 0.032 or 0.048 oz/qt). Mean dry weight and shoot-to-root ratio of planting stock at potting were 37.7 g (0.001 oz) and 1.14 respectively.

Treatment (g N/liter)	Total dry weight (g/plant)			Root-to-shoot ratio		
	6[z]	12	18	6	12	18
0	48.9	86.1	125.9	1.6	2.2	2.0
0.4	57.9	104.2	147.5	1.8	2.7	3.1
0.8	49.8	89.1	138.8	1.6	2.7	4.1
1.2	49.8	97.9	159.7	1.5	2.5	4.3
r^2	*0.02*	*0.03*	*0.41*	*0.06*	*0.04*	*0.76*
P-value	*0.623*	*0.499*	*0.008*	*0.380*	*0.481*	*<0.0001*

[z]Weeks after potting.

Table 2. Nitrogen concentration (% dry matter) in flower, root, new and old shoots of *Rosa* 'Mariandel®' grown in 40% compost amended peat medium fertilized with Osmocote (15N–4P–7.5K–1.8Mg) at N rate of 0, 0.4, 0.8 or 1.2 g/liter (0, 0.016, 0.032 or 0.048 oz/qt). Each value is the mean of eight measurements.

Treatment (g N/liter)	New shoot			Old shoot			Root			Flower	
	6[z]	12	18	6	12	18	6	12	18	12	18
0	2.769	1.478	0.901	0.798	0.538	0.467	1.298	0.820	0.513	1.499	1.213
0.4	2.892	1.887	1.088	0.686	0.654	0.625	1.368	0.951	0.725	1.552	1.293
0.8	2.934	2.434	1.672	0.785	0.850	0.845	1.522	1.199	1.105	2.276	1.770
1.2	2.974	2.352	1.560	0.770	0.737	0.808	1.506	1.260	0.990	1.980	1.577
r^2	*0.30*	*0.77*	*0.75*	*0.01*	*0.37*	*0.73*	*0.24*	*0.67*	*0.65*	*0.45*	*0.53*
P-value	*0.027*	*<0.0001*	*<0.0001*	*0.941*	*0.012*	*<0.0001*	*0.191*	*<0.0001*	*0.0002*	*0.005*	*0.001*

[z]Weeks after potting.

DM at 6 and 12 weeks ($r^2 \leq 0.03$; $P \geq 0.499$). Overall, DM increment in each plant part with the exception of roots increased during the growing period and seemed to show an increasing trend with fertilization rates. Similar results were reported by Craig et al. (5) for *Thuja*, *Cotoneaster* and *Aronia*.

Shoot-to-root ratio. The mean shoot-to-root ratio in all treatments steadily increased over time with the single exception that plants in the control group showed a decrease between weeks 12 and 18 (Table 1). The value calculated after 18 weeks, for instance, was significantly ($r^2 = 0.76$; $P < 0.0001$) affected by fertilization and showed a wider range between 2.0 (for 0 g Osmocote/liter) and 4.3 for 8.1 g Osmocote/liter (0.33 oz/qt). Though differences in taxonomy, age, and method of production limited a direct comparison of our values with others, similar patterns have been observed for *Cryptomeria japonica* (9) and *Acer rubrum* and *Quercus rubra* (13) with increasing N inputs. The DM partitioning of unfertilized (control) plants to roots increased over time from 12% (after 6 weeks) to 38% (12–18 weeks) through 22% (6–12 weeks) (Fig. 1). This indicates that low nutrient supply (especially N) favours disproportionate root over shoot growth. Previous studies by Marschner (16) and Stewart and Metherell (21) have demonstrated that the allocation of C assimilates to the root was influenced by N application; and enrichment of the substrate with N reduces the ratio of root-to-shoot biomass as compared to plants in nutrient-limited environments that stored relatively more carbohydrates in the root (24).

Nitrogen concentration, content, uptake, and partitioning over time. None of the leaves of any plant in any treatment showed chlorotic symptoms after 6 weeks suggesting that the mineral N supplied by the substrate (i.e., initial mineral N plus mineralized N over time) was sufficient to support the growth of 'Mariandel®'. This visual assessment was also confirmed by average plant N concentration (Table 3) that led to insignificant ($r^2 = 0.07$; $P = 0.312$) differences between the control and fertilized treatments. The N concentration in all plant parts (except in new shoots; $r^2 = 0.3$; $P = 0.027$) was also not affected by fertilization rates (Table 2). However, the mean N uptake in the control treatment was lower than total N partitioned to new shoots over 6 weeks (234 mg in Table 3 vs 256 mg in Fig. 2a, respectively). The additional N increment in new shoots was linked with a modest decrease in the initial N content of old shoot (–12 mg) and root (–10 mg) irrespective of the observed dry mass increment in these plant parts. The content of old shoot also decreased in fertilized plants in the range of 10 to 23 mg/plant (Fig. 2b). These results illustrate that early N demand of 'Mariandel®' was not totally met by current uptake but rather supplemented partly by mobilizing stored N. Old shoots, in all cases, appeared to be the principal N source although translocation from roots was also observed under low N input (control). Research reported by Munson et al. (18) described that physiological stage, fertility and environmental conditions, among others, influenced the extent and rate of translocation and this process played an important role in supplementing nutrients for the growth of newly emerging plant parts.

Table 3. Mean plant N concentration, content and uptake of 'Mariandel®' over three sampling intervals. Plants were grown on 4l (#1) containers fertilized with Osmocote (15N–4P–7.5K–1.8Mg) at the initial N rate of 0, 0.4, 0.8 or 1.2 g/liter (0, 0.016, 0.032 or 0.048 oz/qt). Mean total N concentration calculated as a ratio of total plant N content to dry weight whereas N uptake is the difference between two total N contents.

Treatment (g N/liter)	N concentration (%)			N content (mg/plant)			N uptake (mg/plant)		
	6[z]	12	18	6	12	18	6	12	18
0	1.365	0.982	0.666	667.4	845.8	838.2	234.6	178.4	–7.6
0.4	1.485	1.283	0.893	859.6	1337.3	1317.2	426.6	477.7	–20.1
0.8	1.486	1.656	1.361	740.2	1475.7	1888.6	307.2	735.5	412.9
1.2	1.449	1.580	1.301	721.5	1546.8	2076.9	288.5	825.4	530.1
r^2	*0.073*	*0.723*	*0.80*	*0.002*	*0.59*	*0.90*	*0.002*	*0.59*	*0.90*
P-value	*0.312*	*<0.0001*	*<0.0001*	*0.867*	*0.0005*	*<0.0001*	*0.867*	*0.0005*	*<0.0001*

[z]Weeks after potting.

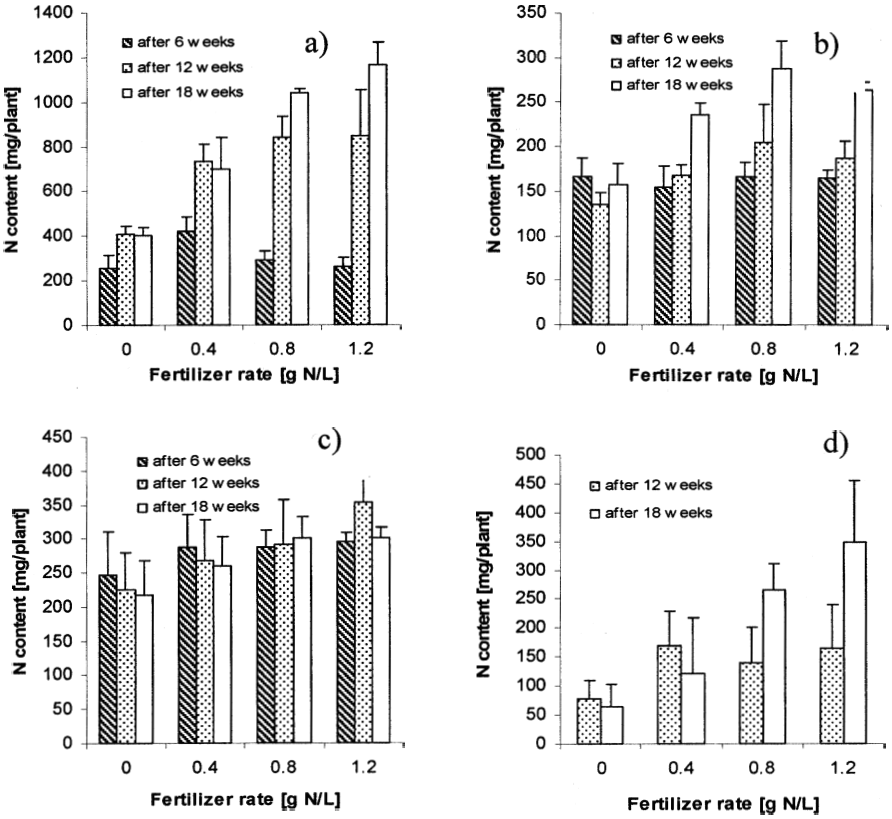

Fig. 2. Nitrogen (N) content of *Rosa* 'Mariandel®' grown in 40% compost amended peat medium as influenced by Osmocote (15N–4P–7.5K–1.8Mg) at N rate of 0, 0.4, 0.8 or 1.2 g/liter (0, 0.016, 0.032 or 0.048 oz/qt): a) new shoots; b) old shoots; c) root; d) flower. Length of the bar shows mean N content ± standard error of the means (n = 4). Each plant was grown in 4 liter (#1) pot. P–value for each sampling time indicates significance level at which at least two treatments differed. N content of old shoots and root at potting were 177 and 256 mg (0.006 and 0.009 oz) respectively.

Although the concentration of N in roots, old and new shoots generally decreased in the second sampling interval (Table 2), a considerable fall was manifest in the control treatments (1.3 to 0.82%, 0.8 to 0.54% and 2.77 to 1.48%, respectively). The decrease in the concentration, however, was less pronounced at high N rates. Chlorotic leaves on control plants coupled with early flowering might have been indications of poor mineral nutrition in the substrate in contrast to fertilized plants that did not show any change in leaf color. The N content of newly developed plant part after 12 weeks (i.e. flower) accounted for 77 and 165 mg at 0 and 1.2 g N/liter treated pots respectively (Fig. 2d), which was 43 and 20% of the corresponding current N uptake. In respect to sampling times, N uptake between weeks 6 and 12 was the highest for all treatments and generally increased with increasing N supply ($r^2 = 0.59$; $P = 0.005$; Table 3). This emphasizes the need for growers to adopt a fertilization program that satisfies the highest nutrient demand of the crop during the active period for N uptake.

Between 12 and 18 weeks, the N concentration of roots in the control dropped drastically from 0.82 to 0.51% (Table 2), while the corresponding decrease in N content was minimal (225 to 217 mg; Fig. 2c) suggesting the presence of greater root dry mass increment in this treatment and dilution (16, 22) contributed to the decrease in N concentration. The N content of new shoots and flowers in this sampling interval decreased in plants grown at 0 and 0.4 g N/liter but increased in plants fertilized with 0.8 and 1.2 g N/liter (Fig. 2a and d). However, the corresponding N content of old shoots in all treatments increased (Fig. 2b) indicating that reduced N was retranslocated from flowers and/or new shoots to old shoots at least in the former two treatments (as their calculated total N uptake was negative; Table 3). Overall, N concentration in all plant parts were affected by fertilization rates at 12 and 18 weeks ($r^2 \geq 0.45$; $P \leq 0.005$; Table 2). Moreover, the N concentration in most plant parts decreased over sampling times elucidating that physiological age has also a profound influence on the mineral nutrient concentration of the whole plant or individual part as suggested by Marschner (16).

Correlation between parameters. The Pearson correlation coefficient (n = 16) between N concentration and N content after 6 weeks was strong in old shoots and roots but not in new shoots (Table 4). At 12 and 18 weeks, however, these two parameters showed a consistently significant ($r^2 \geq 0.5$; $P < 0.05$) correlation in all plant parts with a single exception in flowers after 12 weeks. Nitrogen concentration in each plant part was not significantly ($P > 0.05$) correlated with the respective DM until 18 weeks and the computed r-values were mostly negative. However, the N content accumulation followed a linear trend with dry weight accumulation in each plant part (except old shoots) and was significantly correlated in this study. A strong correlation between N content and DM has also been reported for *Weigela* 'Bristol Ruby' (1), *Thuja* 'Smaragd', *Cotoneaster* 'Coral Beauty' and *Aronia*

Table 4. Pearson correlation coefficients (n = 16) of N concentration (%), N content (mg) and dry biomass (g) in different plant parts of 'Mariandel®' sampled after 6, 12 and 18 weeks of potting.

Plant parts	Correlation between		Weeks after potting 6	12	18
Flower	N concentration	N content	—	–0.04	0.72**
	N concentration	Dry matter	—	–0.41	0.62*
	N content	Dry matter	—	–0.91†	0.99†
New shoot	N concentration	N content	0.05	0.81†	0.92†
	N concentration	Dry matter	–0.13	0.29	0.59*
	N content	Dry matter	0.98†	0.79***	0.86†
Old shoot	N concentration	N content	0.93†	0.86†	0.91†
	N concentration	Dry matter	–0.38	–0.43	–0.30
	N content	Dry matter	–0.01	0.08	0.11
Root	N concentration	N content	0.90†	0.50*	–0.51*
	N concentration	Dry matter	0.21	–0.11	–0.86†
	N content	Dry matter	0.62**	0.80***	0.86†
Aboveground	N content	Dry matter	0.94†	0.69**	0.68**
Total plant	N content	Dry matter	0.88†	0.62*	0.68**

*, **, ***, † represent significance level for P < 0.05, < 0.01, < 0.001 and < 0.0001 respectively.

'Brillianti' (5), *Cotoneaster* 'Skogholm' (12), red oak and red maple (13), and freeman maple (20).

Nitrogen in the fertilizer and the substrate. The pattern of nutrient release from the CRF should be synchronized with the nutrient uptake potential of the crop (5, 13) so that nutrient recovery efficiency is improved (20). In all fertilized treatments, about 50% of initial N in Osmocote was released over 12 weeks (Fig. 3a). The pattern of N released from Osmocote was nearly similar for all fertilized treatments (linear; $r^2 >$ 0.989) indicating that plants in 0.4, 0.8 and 1.2 g N/liter treated pots received an average amount of 80, 126 and 182 mg N per pot and week, respectively, when the contribution of the substrate-compost is excluded.

Six weeks after potting, about 10, 74, 97 and 155 mg N/liter were recovered from the respective pots treated with 0, 0.4, 0.8 and 1.2 g N/liter reflecting the amount of N available for plant roots increased with increased fertilization rates (Fig. 3b). Low recovery of N_{min} (10 mg N/liter; equivalent to 40 mg N/pot) in the control treatment suggests that substrate-compost, which was added at 40% to peat (v/v) could not supply enough N to 'Mariandel®' especially at the later sampling times as confirmed by poor N uptake (Table 2) and chlorotic symptoms. However, compost in this study mineralized at least 96 mg (0.003 oz) and 140 mg (0.005 oz) N/pot during the first and the second 6 weeks, respectively, assuming peat is a relatively stable medium (3). Mineralized N over 6 weeks, for instance, was calculated as (plant N uptake + recovered N_{min} at the end of week 6 + leached N – initial N_{min} at potting) assuming there was no input of N via free-living organisms or irrigation/rain water. However, it would be misleading to conclude that an equal amount of N was released in the fertilized pots because of differences in root growth between fertilized and unfertilized plants (Fig. 1). As stated by Hodge et al. (7), poor availability of mineral nutrients to plants influences the root morphology and leads to finer root production. This situation in turn increases rhizodepositions that enhance the net mineralization of organic N (25).

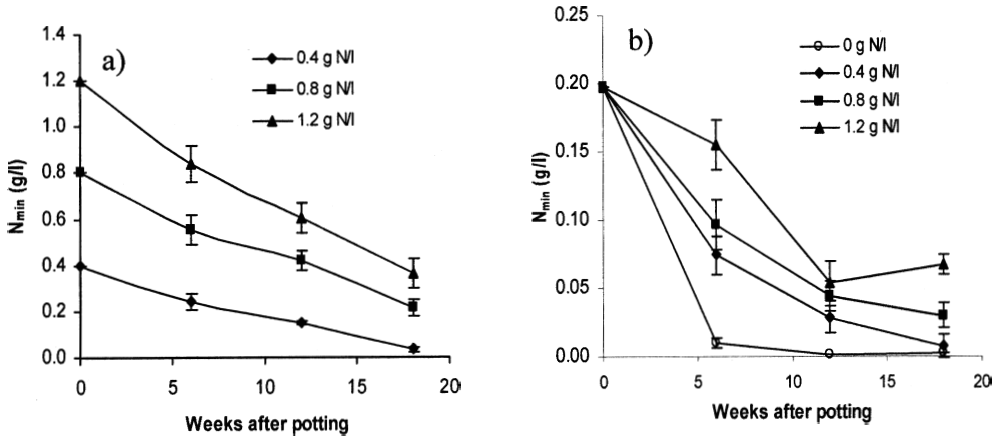

Fig. 3. Mineral N recovered from: (a) fertilizer and (b) substrate over 18 weeks. Each point represents the mean value of eight measurements. Roses were grown in 4 liter (#1) pot and Osmocote (15N–4P–7.5K–1.8Mg) was used as the inorganic fertilizer.

Recovered N_{min} from the control treatment drastically decreased at 12 and 18 weeks (Fig. 3b) as a result of plant uptake and a relatively low N-mineralization rate. Likewise, N_{min} detected in the 0.4 g N/liter (0.016 oz/qt) treatment also decreased to 7 mg/liter [28 mg (0.003 oz) per pot] at the end of 18 weeks suggesting plants in this treatment might experience N deficiency at a later time. This is confirmed partly by negative total N uptake (i.e., the total N content at week 12 exceeded the corresponding amount at week 18 by 20 mg/plant; Table 3; Fig. 2) although each plant showed a mean DM increase of 44 g (1.55 oz) over this sampling interval (Table 1). In contrast, a positive and reasonably high plant N uptake coupled with high recovered N_{min} in the substrate suggesting N was not the limiting factor for plant growth in 0.8 and 1.2 g N/liter (0.032 and 0.048 oz/qt) treated pots. Overall, significant effects of fertilization rates on total plant N concentration, content, and uptake were observed 12 weeks after potting.

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