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Growth and Nutritional Status of *Rosa* 'Mariandel®' Cultivated in Two Potting-Media

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Summary

A pot experiment was conducted to compare the growth and nutritional status of *Rosa* 'Mariandel®' grown in media containing slightly decomposed *Sphagnum* peat [peat] and a mixture of 60 % peat and 40 % substrate-compost [v/v, peat-reduced]. Both media received Osmocote (15N-4P-7.5K-1.8Mg) at N rate of 0.8 g L^{-1}. Plant and media samples were taken at potting and after 6, 12, 18, and 24 weeks. Most physical and chemical properties differed significantly ($P \leq 0.05$) between media types. However, the media had limited or no effect on non-destructive plant measurements including diameter at the base of old shoots, length of longest new shoots, number of flowers and new shoots, crown volume, leaf colour, and disease incidence. Plants grown in the peat-reduced medium, however, produced greater dry mass and had a higher K concentration and content in flowers, roots, old and new shoots. In contrast, the concentrations and contents of N and Mg were higher in the peat-grown plants with no significant difference in P. Therefore, amending peat with 40 % substrate-compost [type I] resulted in plants with similar growth appearances as compared to the pure peat but differed in the nutritional status.

Key words. flower – Osmocote – peat-reduced – root – shoots – slightly decomposed *Sphagnum* peat – substrate compost

Introduction

Because of its optimum water holding capacity (Wilson et al. 2003), adequate porosity (Bohne and Wrede 2005), and unique combination of chemical properties (Reinikainen 1997), peat is one of the most preferred potting-media by nursery crop growers. However, the continual harvesting and utilization of peat are challenged by several groups including environmentalists as well as the waste processing industries. Moreover, the escalating cost of peat forces growers to look for substitutes (Wilson et al. 2003). Promising research findings by Raviv et al. (1998) demonstrated that matured composts are potential substitutes to peat in the production of vegetable and ornamental crops. In Germany, however, composts could only be used in the containers when they fulfil the minimum quality criteria stated in Ral Gz 251 (1999). These matured compost are called substrate-compost and grouped into type I or type II, which possibly substitutes peat up to 40 % or 20 % (v/v) respectively. We have thus used a type I substrate-compost as a partial substitute to peat to grow *Rosa* 'Mariandel®'.

Many researchers have studied the effect of peat substitutes on plant growth (Papenhagen and Hoverath 1999; Zubillaga and Lavado 2001; Wilson et al. 2003; Bohne 2007). In all of these studies, shoot biomass growth was used as a single parameter to choose the best potting-media for container crop production. Apart from growth parameters, however, attention should be given to the nutritional status of the nursery plants. The work of Carbera and Devereaux (1999), for instance, showed that the growth of Carpe myrtle in the landscape was positively correlated with the nutritional status (especially N) of this plant before it left the nursery. In our previous study (Amha and Bohne 2007), we have observed that the early N demand of 'Mariandel®' was partly met by mobilizing stored N in the previous year. Hence, the aim of this work was to compare the growth and nutritional status of *Rosa* 'Mariandel' grown in two nursery media along different developmental stages.

Materials and Methods

Plant material and managements

In this study, a one-year-old *Rosa* 'Mariandel®' grafted onto wild *Rosa canina* (Kordes Söhne GmbH, Germany) was used. Before potting, the shoots and roots of each planting stock were trimmed to ≈10 cm length to achieve a uniform initial planting size. Plants were then potted in 4 L plastic containers filled with either *Sphagnum* peat having H3-H5 on the von Post decomposition scale [peat] or a mixture of 60 % peat and 40 % substrate-compost [v/v, peat-reduced]. This substrate-compost was derived from bio- and green wastes and attained the highest level of maturity and graded as 'type I' (Ral Gz 251 1999). The peat medium was limed by the supplier (Klasmann-Deil-

mann GmbH, Germany) but no lime was added to the peat-reduced medium. Both media were fertilized initially with Osmocote exact standard (15N-4P-7.5K-1.8Mg; longevity of 5–6 months, Scotts, Nordhorn, Germany) at N rate of 0.8 g L^{-1}. Osmocote was mixed into each medium on a per-pot basis to ensure uniform distribution. There were sixty plants per treatment (i.e., medium type). All pots were placed in an outdoor container yard (Hannover, Germany) and irrigated automatically with two spot emitters when the water tension inside the pot reached 0.01 MPa. Water retention in a pot was measured with tensiometers (Tensio-Technik, Geisenheim, Germany). All pots were kept weed free throughout the experimental period (April–September for 24 weeks).

Measurements from the plant and the potting-media

The non-destructive plant measurements were taken from eight randomly selected pots at the beginning of the experiment, and after 6, 12, 18 and 24 weeks. These include the total number of new shoots, length of the longest new shoot, diameter at the base of old shoots, flower number, and leaf colour (visual rating). All shoots that emerged directly from the grafting point were termed as 'old shoots', whereas all newly grown shoots directly from the old shoots were represented by 'new shoots'. The growth of old shoots was, therefore, limited to the diameter increment as they were trimmed to ≈10 cm at the time of potting. The longest canopy diameter (C_1) and the perpendicular diameter to it (C_2) were taken as the two-crown width measurements. The vertical distance from the base of the grafting point to the apex of new shoots at the highest position was considered to be the total plant height (ht.). The crown volume was then calculated as the product of ht, C_1 and C_2 (Calkins et al. 1997). Disease incidence was also scored as a percentage of number of diseased leaves to total number of leaves.

For the destructive plant measurements, a single sampled plant (n = 8) at the beginning and 6, 12, 18 and 24 weeks after planting (WAP) was divided into above and below ground biomass by severing at the surface of the growing medium. The aboveground plant part was further divided into new shoots, old shoots, and flowers (if any). The respective fresh and dry weights of all plant parts were measured before and after oven drying at 70 °C for 96 h. Each plant part was ground to pass through 0.2 mm screen and analyzed for total N by controlled burning with oxygen (Dumas method; Vario MAX CN analyzer, Elementar, Hanau, Germany). To measure phosphorous, potassium and magnesium, the plant material was ashed and dissolved in 0.5 M HCl. Phosphorous was measured using the photometer at 470 nm (Carl Zeiss, Germany), and K and Mg by atomic absorption spectrometer (AAnalyst 100/300, The Perkin-Elmer Corporation, USA) .

At each sampling period (6, 12, 18 and 24 WAP), media loosely adhering to the roots of sampled plants was removed by gentle shaking and thoroughly mixed with the remaining bulk media to monitor the concentrations of NH_4-N and NO_3-N over time. Two sub-samples, equivalent to 150 g wet weight each, were taken from each sampled pot. The Osmocote granules were removed immediately from the first sample while crushed inside the second sample. Both samples were then shaken with 0.05 M $CaCl_2$ solution (1:4 w/v) and the filtrate analyzed for NH_4-N and NO_3-N by liquid flow injection (Auto analyzer; Alpkem Corporation, Oregon, USA). The N_{min} (NH_4-N + NO_3-N) difference between the two samples is a measure for the amount of N_{min} remaining in the Osmocote granules.

Both physical and chemical properties of the preplant potting-media were measured in quadruplicate. The water content – water tension relationship in each medium was determined by a modified International Society for Horticultural Science method (Wrede and Bohne 2000). Bulk and particle densities, total pore space, volumetric water and air contents were also measured using the routine procedures developed for soil improvers and potting-media. The pH and EC (in water and 0.01 M $CaCl_2$) were measured from the media-to-water ratio of 1:5 (v/v), and organic matter as well as ash contents by loss-on-ignition (Vulcan A-1750, Germany). Total N, NH_4-N, NO_3-N, P and K were also determined as described above. Although the use of substrate-compost above 40 % is not recommended for nursery crop production (RAL GZ 251 1999), some of the physical and chemical properties of 100 % substrate-compost were investigated at the time of potting for comparison only.

Statistical analyses

The difference of total plant dry weights between the current and its immediately previous sampling was considered to be the Net Biomass Growth (NBG, in g) over 6 weeks. The Net Biomass Partitioning (NBP), which refers to how much of this NBG is allocated to each plant part, was calculated as the percentage of dry weight change in a particular plant portion to NBG. Nutrient contents of flowers, new and old shoots, and roots at a given sampling time were calculated as the product of the nutrient concentration in the plant part and the respective dry weight of that plant part. Total plant nutrient content was, therefore, determined by summing the contents of flowers, new and old shoots, and roots. Uptake over six weeks was calculated as the difference of total nutrient contents between two consecutive sampling periods. Repeated measures ANOVA was used to analyze the destructive and non-destructive parameters using the SAS program (SAS Instit., Inc. 9.1 for Windows, Cary, NC). A one way ANOVA was then carried out to compare means at each sampling period. Means were separated using Tukey comparison test at $P \leq 0.05$ unless otherwise stated. Simple linear regression analysis was also performed between the selected parameters to evaluate their relations.

Results and Discussion

Initial media characterization

Chemical properties such as NH_4-N, NO_3-N, P and K contents were statistically higher in the peat-reduced medium compared to peat alone (Table 1a). The concentrations of NH_4-N and NO_3-N in the 100 % substrate-compost were 5 and 99 mg L^{-1} respectively (data not shown). The salt content in compost amended peat medium was considerably higher than the threshold limit given for most *Rosa* species, 1.8 dS m^{-1} (Handreck and Blank 1989). Under such circumstances, flooding at potting might be essential to reduce the effects of soluble salts on the early root growth of sensitive plant species. The per-

Table 1. Some of the selected chemical (a) and physical (b) properties of peat and a mixture of 60 % peat and 40 % substrate-compost (peat-reduced) media at the time of potting. Values are means ± standard deviations (n = 4).

Substrate types	a. Chemical properties								
	NO_3-N (mg L^{-1})	NH_4-N (mg L^{-1})	P (mg L^{-1})	K (mg L^{-1})	OM (%, m/m)	Ash (%, m/m)	EC (dS m^{-1})	[1]pH	[2]pH
Peat-reduced	15.6 ± 1.2	109.6 ± 0.0	75.4 ± 0.8	435.6 ± 2.0	39.4 ± 1.3	60.6 ± 1.3	4.3 ± 0	6.4 ± 0.1	5.7 ± 0.1
Peat	8.5 ± 1.1	17.2 ± 0.4	0.9 ± 0.0	7.7 ± 0.2	91.3 ± 0.4	8.7 ± 0.4	0.5 ± 0	6.9 ± 0.1	5.7 ± 0.0
P-value	*	***	†	†	***	***	†	ns	ns

Substrate types	b. Physical properties								
	Dry bulk density (g L^{-1})	Particle density (g L^{-1})	Total pore space (%, v/v)	Air content (%, v/v)	[3]WC at 0.001 MPa (%, v/v)	WC at 0.005 MPa (%, v/v)	WC at 0.010 MPa (%, v/v)	Available water (%, v/v)	Water buffering capacity (%, v/v)
Peat-reduced	288.4 ± 6.7	2.14 ± 0.1	86.5 ± 0.1	17.5 ± 0.1	69 ± 0.2	40.1 ± 0.2	38.0 ± 0.1	31.0 ± 0.2	2.1 ± 0.3
Peat	126.8 ± 0.8	1.71 ± 0.0	92.4 ± 0.7	15.4 ± 0.5	77 ± 0.6	45.5 ± 0.1	44.9 ± 0.2	32.1 ± 0.6	0.6 ± 0.1
P-value	†	***	***	ns	***	***	***	ns	**

[1]substrate: water at 1:5 ratio [v/v]; [2]substrate: 0.01 M $CaCl_2$ at 1:5 ratio [v/v]; [3]water content.
NS, *, **, ***, † Nonsignificant or significant at $P \leq 0.05$, < 0.01, < 0.001 or < 0.0001

cent of organic matter was higher in peat compared to peat-reduced. Since the peat medium was limed before purchase, both media had a similar pH that falls within the recommended ranges (5.0 to 6.5) for growing many horticultural crops (Reinikainen 1997).

The air capacity and total porosity of 13 commercially available potting-media in Germany varied from 7.0 to 31.4 % and 87.0 to 94.3 %, respectively (Bohne and Wrede 2005). Our calculated air volume and total pore space (Table 1b) were thus fitting in the above ranges and are in agreement with the International Substrate Manual (2000). Total porosity and water contents at 0.001, 0.005 and 0.01 MPa were different between media. Both media were, however, similar in air content. The available water, which describes the volume of water released between 0.001 and 0.01 MPa (De Boodt and De Waele 1968), was statistically ($P > 0.05$) at par suggesting similar irrigation requirements between the two potting-media. The dry bulk density of the peat-reduced medium was nearly 2.3 times higher than that of peat (Table 1b) illustrating that the addition of 40 % substrate-compost to peat can create handling problem especially when big containers are used.

Non-destructive growth parameters

Although a higher variability within replications led to insignificant ($P > 0.05$) differences between the tested treatments, the canopy volumes (dm^3) that determine the plant growth index (Beeson and Keller 2001) were 38 ± 10 and 70 ± 13 (in the peat-reduced medium) compared with peat grown plants (30 ± 5 and 65 ± 7) after 12 and 18 weeks, respectively (data not shown). It was also found that the mean flowers count after 12 weeks was 8 in peat grown plants and 6 in peat-reduced. However, plants grown on both media produced about 12 additional flowers during the next sampling period (18 WAP). Most of the flowers were, however, dropped during the last sampling interval (between 18 and 24 WAP). Throughout the growing season, there was no difference in plant leaf colour (i.e., they were remained visually green). Overall, potting-media had limited or no significant ($P > 0.05$) effect on most considered non-destructive plant measurements. Based on the procedure outlined by Wilson et al. (2003), which encompasses leaf colour, disease incidence, plant form, flower number and fitness to market, all plants in both media were graded as 'high quality' after 12 weeks. At the end of 18 weeks, the rating in the peat grown plants was lowered by one level as a result of disease incidence (i.e., about 10 % of total plant leaves were infected by black spot while none were infected in the peat-reduced medium). Although the disease incidence in the peat grown plants increased beyond 50 %, approximately 25 % of total leaves in the peat-reduced medium had also showed similar symptom after 24 weeks. In both media, the infection was severe on the lower (older) plant leaves. No fungicides were, however, applied throughout the growing season.

Plant growth and dry mass production

The initial mean total dry weight of each planting stock was 30.9 ± 1.7 g. Due to a delayed shoot growth in the peat-reduced grown plants, the total dry mass production in this medium was lower than that of the peat grown plants after six weeks (Table 2). This delay in shoot growth could be induced by the higher initial EC content (Table 1a) as suggested by Handreck and Blank (1989). The NBP in both media, however, followed a similar trend: new shoot > old shoots > root (Table 2). The calculated NBG for the latter two sampling periods was greater for the peat-reduced grown plants and was in agreement with the plant growth index results (data not shown). Various researchers (including Zubillaga and Lavado

Table 2. Mean shoot-to-root ratio [S:R], net biomass growth [NBG, in g] and net biomass partitioning [NBP, in %] of 'Mariandel®' cultivated in two potting-media that were initially fertilized by Osmocote exact standard at 0.8 g N L^{-1} (3.2 g pot^{-1}). NBG over six weeks was calculated as the difference between total plant dry weights in two consecutive samplings. NBP values indicate how much of that NBG allocated to each plant part when expressed in %. Mean plant dry weight at potting was 30.9 g $plant^{-1}$ (S:R = 0.56 ± 0.05).

Week after potting	Peat grown plants						Peat-reduced grown plants					
	S:R	NBG	NBP				S:R	NBG	NBP			
			F	NS	OS	Root			F	NS	OS	Root
6	0.98	+10.0	0.0	38.8	50.6	10.6	0.74	+6.2	0.0	61.8	28.7	9.7
12	2.40	+35.7	3.5	81.5	12.0	3.0	2.06	+38.9	4.5	79.9	9.9	5.7
18	3.17	+37.2	15.1	63.8	17.5	3.6	3.33	+48.6	12.6	63.8	10.6	13.1
24	1.81	−6.9	–[a]	–	–	–	2.02	+8.5	–	–	–	–

Flower (F), new shoot (NS), old shoot (OS), [a]not calculated

2001; Wilson et al. 2003; Bohne 2007) have also reported significant effects of potting-media on plant biomass growth. Unlike the NBG data, the patterns of NBP was unaffected by media types (Table 2). NBG in the peat-reduced medium was positive (8.5 g $plant^{-1}$) over the last sampling interval but negative for the peat grown plants (−6.9 g $plant^{-1}$) because of excessive leaf and flower losses in this medium. Despite the normal physiological processes (e.g. aging), in both media, shedding of leaves was enhanced by the occurrence of a high disease incidence. It was, however, observed that the dry mass of the old shoots and roots were generally increased during the last sampling interval to suggest a shift in source-sink relationship for photosynthetic product.

Nutrient concentrations, contents and uptake

The concentration data are not tabulated here in this paper but their details can be accessed in the unpublished thesis report (Amha 2006; Leibniz University of Hannover, Germany). At potting, however, the concentration of N in the old shoots was lower than that of the roots (0.93 ± 0.03 % vs. 1.55 ± 0.04 % dry weight). The mean percent of P, K and Mg in aerial parts were 0.13 ± 0.01, 0.57 ± 0.05 and 0.15 ± 0.01, respectively. The corresponding concentrations in the roots were 0.17 ± 0.01, 0.31 ± 0.02 and 0.17 ± 0.01. After six weeks, all nutrient concentrations in each plant part (except K in roots) were not statistically ($P > 0.05$) affected by the tested treatments. However, concentrations of N and K in new shoots ($P < 0.05$), old shoots ($P \leq 0.01$), and roots ($P \leq 0.05$) were significantly affected by media type after 12 weeks (Amha 2006; unpublished thesis report; Leibniz University of Hannover, Germany). In the last two samplings, the percent of N and Mg in new shoots, old shoots, and roots were statistically higher in the peat grown plants (as oppose to K, which was higher in the peat-reduced medium) with no significant ($P > 0.05$) difference in P. Overall, flowers had the highest and old shoots had the lowest nutrient concentrations of all plant parts tested.

Plant N uptake, which was calculated as the difference of total N contents between two consecutive sampling periods, was higher in the peat medium until week 18 (Fig. 1a). The highest N uptake in this medium (620 mg $plant^{-1}$) was observed between week 6 and 12, which was approximately 2.3 fold higher than the uptake in the first and the third sampling intervals. The corresponding total N uptake in the peat-reduced grown plants was 588 mg, and accounted for 4.1 and 2.7 times the respective uptake in the first and the third six weeks. In our previous work (Amha and Bohne 2007), the N uptake of 'Mariandel®' in the unfertilized peat-reduced medium after 6 weeks (234 mg $plant^{-1}$) was statistically similar to 1.2 g N L^{-1} Osmocote received treatment (288 mg $plant^{-1}$). The N-uptake of unfertilized plants in subsequent samplings (12, 18 and 24 WAP) was, however, by far less than that of all fertilized treatments (0.4, 0.8 and 1.2 g N L^{-1}) to suggest that N supplied by substrate-compost was insufficient to support good plant growth right after 6 weeks. Plants in both media showed statistically ($P > 0.05$) similar P uptake throughout the growing season (Fig. 1b). Despite the higher dry mass production (data not shown) and higher initial P content in the peat-reduced medium (Table 1a), the slightly lower P uptake in this medium might be partly induced by leaching and/or surface fixation.

The uptake of K was enhanced by the addition of 40 % substrate-compost into peat (Fig. 1c). Between week 6 and 12, the total K uptake in the peat-reduced medium was 615 mg $plant^{-1}$ (13.1 and 3.3 times higher than uptake over the first and the third sampling intervals) but only 448 mg $plant^{-1}$ (6.8 and 2.7 times, respectively) in the pure peat medium. Since the amount of added Osmocote was equal (1.6 g K pot^{-1}), the greater K uptake in the peat-reduced medium is primarily attributed to its high initial K content (Table 1). Mg content in the plant was positively ($r^2 \geq 0.91$; $P < 0.05$; $n = 40$ plants) correlated with N (data not shown) elucidating a higher Mg uptake by the peat grown plants (Fig. 1d). In summary, total N, P, K and Mg contents were significantly and positively correlated with plant dry weights (data not shown) as was reported for container grown *Prunus laurocerasus* 'Otto Luyken' (Bohne 2007).

N_{min} in the pots

Different factors in the soil including temperature, moisture and physico-chemical properties are known

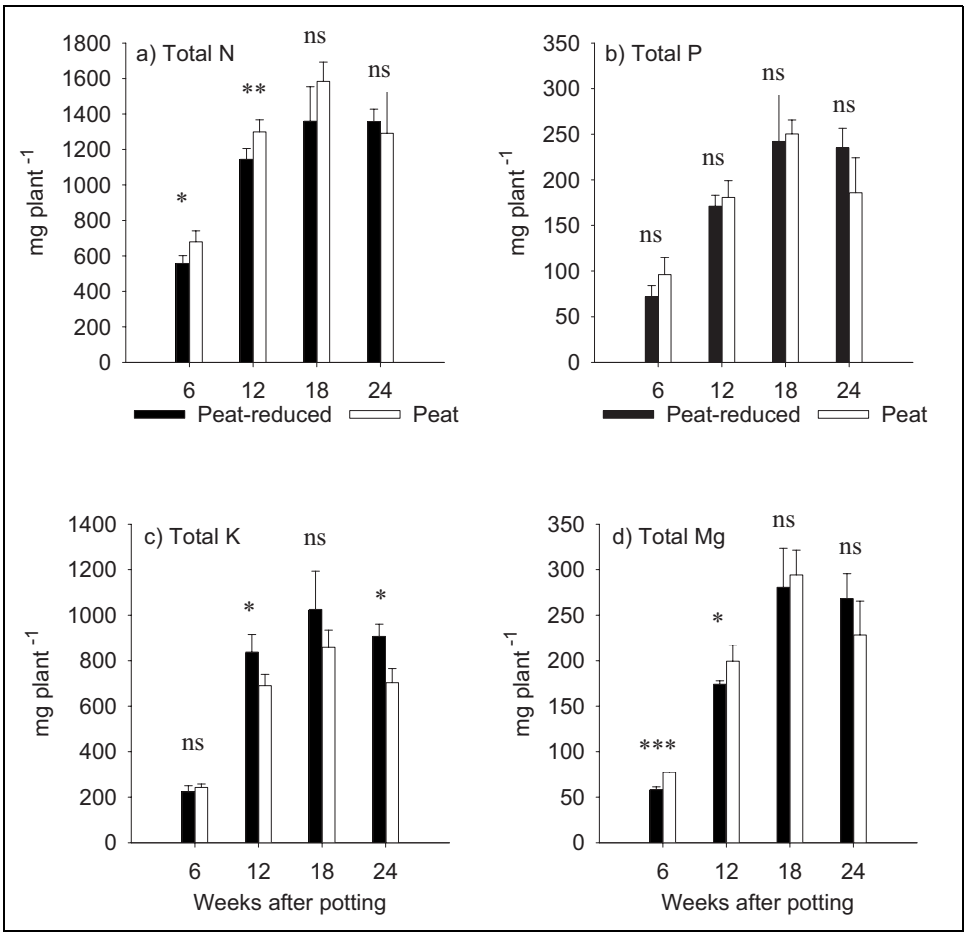


Fig. 1. Total nutrient contents in *Rosa* plant (mg plant^{-1}) grown in peat or a mixture of 60 % peat and 40 % of substrate-compost. Average plant nutrient contents at potting were 411N-40P-176K-46Mg. Uptake over six weeks can be calculated as a difference of total nutrient content between two consecutive sampling periods. Both media were fertilized initially with Osmocote (15N-4P-7.5K-1.8Mg) at N rate of 0.8 g L^{-1} (3.2 g pot^{-1}). The length of the bar shows standard deviation for n = 8. $^{ns, *, **, ***}$Nonsignificant or significant at $P \leq 0.05$, 0.01 or 0.001, respectively.

to influence the nutrient releasing profile of controlled release fertilizers (Miner et al. 1978), which in turn affects the availability of nutrients for plant growth. Although most physico-chemical properties differed significantly between media types (Table 1), the amount of N released from the Osmocote was statistically ($P = 0.738$) at par (data not shown). The nutrient releasing pattern of Osmocote exact standard was not also affected by the rate of Osmocote addition (Amha and Bohne 2007). The N releasing rate over 24 weeks can thus be explained by the linear relation ($y = 29.054x + 25.773$; $r^2 = 0.97$; $P < 0.01$; $n = 72$; where x and y refer to sampling weeks and N released in mg L^{-1}, respectively) suggesting each plant was supplied with an average N rate of ≈120 mg/week. This equation, however, can only work for the added 800 mg L^{-1}.

Detectable N_{min} after 6 weeks was 97 and 117 mg L^{-1} in the peat and peat-reduced medium, respectively (data not shown). Despite the presence of considerable amount of leached N (294 mg L^{-1} in the peat-reduced medium compared to 176 mg L^{-1} in peat), the statistically ($P \leq 0.05$) higher N_{min} in the former medium was partly due to high initial N content (Table 1a) and low N-uptake (Fig. 1a). In contrast, $CaCl_2$ extractable N_{min} after 12 weeks was significantly ($P \leq 0.05$) higher in the peat medium (data not shown). Both media, however, contained similar N_{min} after 18 and 24 weeks.

Conclusion

Amending peat with 40 % substrate-compost [type I] yielded plants with similar growth appearances compared to the pure peat. However, plants grown in the compost-containing medium had a higher K concentration/content, lower N and Mg contents, and similar P content to the control peat medium. Despite the observed similar plant growth, the higher nutritional contents (especially N) by the peat grown plants could be taken as an advantage upon field transplantation.

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References

Amha, Y. and H. Bohne 2007: Seasonal biomass and nitrogen accumulation of *Rosa* 'Mariandel®' grown in compost amended peat at different fertilization rates. J. Environ. Hort. **25**, 197–203.

Beeson, R.C. and K.G. Keller 2001: Yard waste compost as a landscape soil amendment for Azaleas. J. Environ. Hort. **19**, 222–225.
Bohne, H. and A. Wrede 2005: Investigations of physical properties of substrates. Europ. J. Hort. Sci. **70**, 1–6.
Bohne, H. 2007: Influence of a peat-free substrate and kind of fertilizer on the nitrogen- and water balance and on plant growth. Europ. J. Hort. Sci. **72**, 53–59.
Cabrera, R.I. and D.R. Devereaux 1999: Crap Myrtle post-transplant growth as affected by nitrogen nutrition during nursery production. J. Am. Soc. Hort. Sci. **124**, 94–98.
Calkins, J.B., B.R. Jarvis and B.T. Swanson 1997: Compost and rubber tire chips as peat substitutes in nursery container media: Growth effects. J. Environ. Hort. **15**, 88–94.
De Boodt, M. and N. De Waele 1968: Study on the physical properties of artificial soils and the growth of ornamental plants. Pédologie **181**, 275–300.
Handreck, K. and N. Blank 1989: Growing media for ornamental plants and turf. New South Wales University Press, Kensington.
International Substrate Manual 2000: Analysis, characteristics, recommendations. Elsevier International Business Information, Doetinchem.
Miner, G.S., J.P. Lilly and D.L. Terry 1978: Nitrogen release characteristics of isobutylidene diurea and its effectiveness as a source of N for flue-cured tobacco. Agron. J. **70**, 434–438.
Papenhagen, A. and I. Hoverath 1999: Optimierung und Standardisierung eines Kompost-Kultursubstrates für Gehölze. Gartenbau Report **11**, 12–15.
Ral Gz 251 1999: Güte- und Prüfbestimmungen sowie Durchführungsbestimmungen für die Verleihung und Führung des RAL-Gütezeichens Kompost. Hrsg.: RAL Deutsches Institut für Gütesicherung und Kennzeichnung, St. Augustin.
Raviv, M., Y. Zaidman and Y. Kapulnik 1998: The use of compost as peat substitute for organic vegetable transplants production. Compost Sci. & Util. **6**, 46–52.
Reinikainen, O. 1997: Peat, the ultimate material for horticultural use? In: Schmilewski, G. (ed.): Proceedings of the International Peat Conference: Peat in horticulture – its use and sustainability, November 2–7, Amsterdam, The Netherlands, 105–111.
Wilson, S.B., P.J. Stoffella and D.A. Graetz 2003: Compost amended media and irrigation system influence containerized perennial *Salvia*. J. Am. Soc. Hort. Sci. **128**, 260–268.
Wrede, A. and H. Bohne 2000: Die M-ISHS-Methode – eine praxisorientierte Untersuchungsmethode zur Ermittlung der Kennwerte des Luft- und Wasserhaushalts von Kultursubstraten. Gartenbauwissenschaft **65**, 199–201.
Zubillaga, M.S. and R.S. Lavado 2001: Biosolids compost as component of potting media for bedding plants. Gartenbauwissenschaft **66**, 304–309.

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