Reducing peat and growth regulator input in camellia pot cultivation

F. Larcher, A. Berruti, P. Gullino, V. Scariot

Department of Agronomy, Forest and Land Management, Faculty of Agriculture, University of Turin, Turin, Italy

Abstract

Larcher F., Berruti A., Gullino P., Scariot V., 2011. **Reducing peat and growth regulator input in camellia pot cultivation**. Hort. Sci. (Prague), *38*: 35–42.

Regulating plant development plays an important part in *Camellia japonica* L. pot production. Cultivation usually occurs on peat-based substrate and growth control is performed with triazoles application. However, there is an increasing need for suitable peat alternatives and more effective protocols. This study evaluated the effectiveness of three different dosages (50, 100, 200 mg/l) and two application protocols (foliar spray, once or twice) of paclobutrazol on two *C. japonica* cultivars grown on eight different substrate mixtures. The substrates were composed of four peat substitutes (local green compost, pumice, composted coconut peat, and pine bark) mixed with the standard substrate at 30–40% by volume. Treated plants showed reduction in most of the growth-related parameters, enhancement of ornamental value and an overall plant health improvement. Basically, one application of paclobutrazol 50 mg/l was sufficiently active. Among substrates, pine bark appeared to be a suitable partial peat alternative. Considering their lower cost and effective performances, pumice and coconut peat proved suitable alternatives, too.

Keywords: flowering; plant development; paclobutrazol; ornamental plants; substrates

Abbreviations: Ø – diameter; BDW – branches dry weight; cv – cultivar; DB – Dr. Burnside; FC^* – flower chroma; F$h°$ – flower hue angle; FL^* – flower lightness; FN – flower number; FV – flower conical volume; H – height; H/Ø – height-diameter ratio; LC^* – leaf chroma; LDW – leaves dry weight; LG – leaf gloss; L$h°$ – leaf hue angle; LL^* – leaf lightness; LN – leaves number; MR – mortality rate; NP – Nuccio's Pearl; PBZ – paclobutrazol; PGR – plant growth regulator; RC – root colour; RD – root density; RT – root thickness; SPAD – chlorophyll content; Sub – substrate

Plant height and flowering are two highly controversial features of greenhouse ornamental plant pot cultivation. The tendency to grow taller than desired and the absence of synchronized flowering was shown to hinder the achievement of marketable ornamental plants (Banko, Landon 2005).

There are different categories of control tools available to producers: biological, mechanical, environmental, and chemical. Biological control is the newest and the highest yield potential method, but still does not represent a reliable and universal technique (Bailey, Whipker 1998). Mechanical and environmental control relies on knowledge of how plant growth can be affected by cultural practices and environmental conditions. It includes many techniques like shoot brushing, impedance,

Supported by the Regione Piemonte, Project No. 345/12–29.11.2004

Table 1. Composition of the substrates tested and their relative cost referred to the cost of the standard substrate (arbitrarily defined as 100 units)

Substrate	Composition (% v/v)	Relative cost (units)
S	89% *Sphagnum* peat + 11% agriperlite (standard substrate)	100
SGC*	70% standard substrate + 30% green compost	81
SP*	70% standard substrate + 30% pumice	111
SCP*	70% standard substrate + 30% coconut peat	102
SPB*	70% standard substrate + 30% pine bark	133
SGCP	60% standard substrate + 20% green compost + 20% pumice	95
SGCCP	60% standard substrate + 20% green compost + 20% coconut peat	89
SGCPB	60% standard substrate + 20% green compost + 20% pine bark	109

*Substrate mixture previously tested for camellia pot cultivation (Larcher, Scariot 2009)

and plant shaking (Latimer 1998), negative difference between day and night temperature (DIF), and photoperiod fluctuation (Torre, Moe 1998), light quality and intensity shifts (Moe et al. 1991) and temperature dropping (Myster, Moe 1995). The most used and effective type of control, however, is the one that involves the application of chemical growth retardants. Several plant growth regulators labelled for use in floriculture, such as the triazoles and pyrimidines, were developed to reduce stem elongation by inhibiting the synthesis of gibberellins (Rademacher 1989, 1992; Brown et al. 1997). A secondary effect linked to the inhibition of gibberellic acid biosynthesis is, for some plant genus including *Camellia*, an early and enhanced flowering (Halevy 1983). However, these chemicals may also raise phytotoxic symptoms, such as chlorosis and leaf or flower injuries, probably because correct dosage and timing are unknown, with consequent impacts on costs and on the environment (Whipker et al. 2001). Thereby, arranging dosage, timing, target, and application technique represents an important tool and a necessary step for efficiently setting genotype and environmental conditions related protocols (Davis, Andersen 1989; Bailey 1991).

Regulating plant development plays an important part in potted *Camellia japonica* L. cultivation and is unfortunately very challenging. The few studies available on *Camellia* genus generally indicated triazoles (paclobutrazol, uniconazole) as the best molecules able to assure a suitable growth control (Wilkinson, Richards 1988; Song, Lee 1995; Banko, Landon 2005).

Another remarkable topic related to pot cultivation is the increasing need for suitable peat alternatives. Recent studies (Hernandez-Apaolaza et al. 2005; Ribeiro et al. 2007; Larcher, Scariot 2009) emphasized the interest in using abundant, high quality environmental-friendly substrates, with a view to sustainable floriculture. As substrates can affect growth regulation (Million et al. 1998a, b; Di Benedetto, Molinari 2007), it appeared necessary to perform growth regulation on brand new substrate mixtures in order to evaluate the role and possible interactions between these two cultivation factors.

This study evaluated the effectiveness, controlling both vegetative development and flowering, of three different dosages and two application protocols of paclobutrazol on two *C. japonica* cultivars grown on eight different substrate mixtures. Results will aid growers in rationalizing camellia cultivation through the use of more effective protocols.

MATERIAL AND METHODS

Plant material and growth conditions

The cultivation of two *C. japonica* cultivars, Nuccio's Pearl (NP; white-pink flowers) and Dr. Burnside (DB; red flowers), selected according to their commercial and ornamental value, lasted two years (2006–2008) and was carried out in a frost-free greenhouse with no additional light of a commercial nursery devoted to produce acidophilus ornamental plants, located in the Piedmont district (Northern Italy). Seven alternative substrate mixtures, among which four previously tested by Larcher and Scariot (2009), and the standard substrate (89% commercial *Sphagnum* peat and 11% agriperlite) were evaluated (Table 1). The substrates were composed of four peat substitutes (local green compost, pumice, composted co-

Table 2. The eight plant growth regulator (PGR) treatments performed in the experiment. Dosages and number of applications of six paclobutrazol (PBZ) and two control treatments are shown

PGR	Active ingredient	Dosage (mg/l)	No. of applications
WX1	water control	–	1
P50X1	PBZ	50	
P100X1	PBZ	100	
P200X1	PBZ	200	
WX2	water control	–	2
P50X2	PBZ	50	
P100X2	PBZ	100	
P200X2	PBZ	200	

conut peat, and pine bark) mixed with the standard substrate at 30–40% by volume. Commercial *Sphagnum* peat (Alce and Silver Torf) was supplied by Agrochimica (Bolzano, Italy) while coconut peat and pine bark by Tref Ego Substrate BV (Moerdijk, Netherlands). Green compost (waste mainly originating from gardens and parks) and pumice were obtained by local producers (Cooperativa Sociale Risorse, San Bernardino Verbano, Italy). The physical, chemical, and biological characteristics of the substrates which were assessed and compared with desired values as described by Larcher and Scariot (2009), were generally within the acceptable ranges for camellia plant container production (data not shown).

Plants were cultivated following the ordinary protocol, as described by Larcher and Scariot (2009). In spring 2007, plant growth regulation took place. The cultivation ended in April 2008, when the flowered pots were suitable for the market.

Plant growth regulation and experimental design

Three paclobutrazol [PBZ; IUPAC chemical name (2RS, 3RS)-1-(4-Chlorophenyl)-4,4-dimethyl-2-(1H-1,2,4-triazol-1-yl)pentan-3-ol] concentrations (50, 100, and 200 mg/l, Cultar®, 25% v/v, Syngenta Agro S:A:, Madrid, Spain) and a water negative control were finely sprayed once (May 24, 2007) or twice (May 24 and June 8, 2007), with a volume of 15 to 20 ml until foliar dripping point was reached, in order to slightly moisten the substrates. The eight plant growth regulator treatments (PGR, Table 2) were tested on a sample of 576 plants of each cultivar with a completely randomized experimental design. A nested design was devised with three factors (cultivar, substrate mixture, and PGR application protocol) and 9 replications. Each pot was randomly allocated to one of the treatment regimes and placed on greenhouse benches.

Morphological parameters and quality evaluation

Plant growth and ornamental characteristics were monitored during the main different cultivation phases (potting, before re-potting, before and after branching, and at the end).

Plant height (H) and diameter (Ø), measured across the widest side of the plant, were recorded for each pot. To indirectly measure leaf chlorophyll content and plant health (Smith et al. 2004), the Chlorophyll Meter SPAD-502 Konica Minolta (Nieuwegein, Netherlands), characterized by a measuring accuracy of ± 1.0 SPAD unit, was used. Measurements were performed on 4 leaves randomly chosen within each replicate, being each measure the mean value of 2 measures on the same leaf. When the plants reached commercial size, the aerial part of each plant was oven-dried at 90°C, and dry weights were determined for total leaves (LDW) and branches (BDW). To assess root quality, density (RD), thickness (RT), and colour (RC) of the visible roots at the substrate surfaces (side and bottom) were visually evaluated by three referees using respectively four classes of roots covering (1 = 0–25%, 2 = 26–50%, 3 = 51–75%, 4 = 76–100%), root thickness (with class 4 indicating thicker roots), and root colour (with class 4 indicating darker roots), respectively. Mortality rate (MR) at the end of the experiment was also calculated. For aesthetic value, plant height, and average diameter were used to calculate an ornamental parameter, the height per diameter ratio (H/Ø), according to Meijon et al. (2009). At full bloom, one randomly chosen flower and leaf per replication was taken in consideration for further analyses. Flower conical volume (FV) was calculated according to the following formula: $FV = \pi \times (FØ/2)^2 \times FD/3$ (with *FØ* being flower diameter and *FD* representing flower depth). Colour (L^*, a^*, b^* space) variations and gloss were measured by means of spectrophotometer CM-2600 Konica Minolta sensing Inc. (Osaka, Japan). Chroma (C^*) and hue angle ($h°$) were calculated according to Onozaki et al. (1999). At last, total flowers produced during the whole flowering period and leaves number at the end of cultivation (FN and LN, respectively) per plant were counted.

Statistical analysis

To analyze camellia growth, health, and ornamental related data and to assess interactions among fixed factors (cultivar, substrate mixture, and plant growth regulator treatment), results were subjected to a univariate analysis of variance (UNI-ANOVA). All data were post-hoc tested using Ryan-Einot-Gabriel-Welsch-*F* test (REGW-*F*), by means of the SPSS statistical package (version 16.0; SPSS Inc., Chicago).

RESULTS AND DISCUSSION

Plant growth regulator treatments

PGR effects were observed on every parameter except for RC. Plants treated with PBZ showed H, Ø, LDW, BDW, and SPAD clearly different from controls (Table 3a). Fewer differences on root characteristics were detected. RD was affected only by P100X1 (1.91). Treatments P50X2 to P200X2 caused root thickening while no effects were seen on RC. Considering ornamental characteristics, PBZ influenced H/Ø, FN, FL^*, FC^*, and F$h°$. Few differences were detected among PBZ treatments. H/Ø was closer to 1 than in control plants, pointing to an improved growth control. FN and FC^* were statistically higher, while FL^* was lower, indicating that PBZ treatments led to darker and more vivid petals. F$h°$ showed a hue switch trend towards more reddish colors in PBZ treated camellias, especially for P100X1 (27.63) and P200X2 (28.81). Concerning flowering time, all plants showed the same trend (data not shown), starting gradually at the beginning of January and reaching the peak in mid-March, 2008.

Growing media

Morphological characteristics were influenced by all substrate mixtures except for LL^* and FC^* (Table 3b). In SGC, H, and Ø were reduced (23.84 and 22.35) while flowering was enhanced (2.96), suggesting a substrate based control. In contrast to other growing media, which generally matched camellia pot cultivation, in this medium plants appeared to be undergoing physiological stress. In detail, SGC dramatically reduced LN (27.13) and BDW (2.94), slightly negatively affected SPAD (77.20) and caused an abnormally darker root color (2.58) and less developed root systems (1.80). A higher MR (30%) was also observed compared to the average of all other substrates (5%). Best results in growth were achieved for plants cultivated in SP and SPB, which showed higher values for H (42.43 and 41.02), LDW (15.16 and 15.59), BDW (7.13 and 6.76), SPAD (79.32 and 79.46), and lower MR (3% and 1%). Generally peat substitution, except in SPB, negatively affected RD while enhancing SPAD in most of the substrates (SP, SPB, SGCP, SGCPB). From an ornamental point of view, the situation was more complex. H/Ø was closer to 1 in SGC (1.11) but, as above mentioned, this medium perturbed plant growth while SP and SPB provided the highest ratios (1.58 and 1.51). Substrate mixtures differently affected leaf and flower color. LC^* resulted higher in S (12.63) and lower in SGCP (11.29). $Lh°$ resulted higher in SP (126.25), SGCP (126.25), and SGCCP (126.44). In the latter, leaf gloss (LG) showed the lowest value (10.17). Concerning FL^*, plants grown on SGC, SCP, and SPB presented slightly lighter hues (65.89, 65.50, and 65.60) with respect to S (63.15). FN was generally not affected by growing media, except for SCP, in which plants produced on average fewer flowers (1.36).

Interactions

Interactions among fixed factors (cultivar, substrate mixture and plant growth regulator treatment) were significant for every parameter (Table 3c). In particular, significant interactions among all possible factor combinations (cultivar and substrate; plant growth regulator and cultivar; plant growth regulator and substrate; plant growth regulator, cultivar and substrate) were found in H, BDW, RD, LN, LC^*, LG, FN, FL^*, and F$h°$. Hence, in order to better analyze different PBZ application effects, UNI-ANOVA and Post-hoc test (REGW-*F*) were performed on data referring to the two cultivars grown only on standard substrate (S). Results on growth parameters (data not shown) showed that all PBZ treatments similarly affected H and Ø, contrasting control treatments, while for the other parameters few or no differences among treatments were highlighted. The effect of the interaction between growth regulation and substrate was ana-

Table 3. Main effects of plant growth regulator treatments (PGR), substrates (Sub), cultivars (cv), and interactions among fixed factors on growth of two *Camellia japonica* cultivars

	Growth									Ornamental characteristics											
	H (cm)	Ø (cm)	LDW (g)	BDW (g)	SPAD	RD	RT	RC	MR (p)	H/Ø	LN	*LL**	*LC**	*Lh*°	LG	FN	FV (cm^3)	*FL**	*FC**	*Fh*°
(a) Plant growth regulator treatments																				
WX1	47.46$^{b\#}$	31.08^{d}	14.98^{c}	7.02^{b}	77.32^{a}	2.27^{b}	1.50^{ab}	1.55	0.12^{b}	1.54^{b}	46.63^{ab}	29.31^{a}	12.87^{b}	125.06^{a}	14.37^{c}	1.32^{a}	174.15^{b}	66.27^{c}	27.80^{a}	42.65^{d}
WX2	46.55^{b}	28.81^{c}	14.58^{c}	6.99^{b}	77.49^{a}	2.33^{b}	1.43^{a}	1.88	0.12^{b}	1.65^{b}	53.12^{b}	31.48^{b}	11.60^{a}	126.63^{d}	12.69^{b}	1.30^{a}	142.28^{a}	67.18^{c}	26.50^{a}	46.10^{e}
P50X1	34.09^{a}	25.32^{ab}	11.81^{b}	5.38^{a}	79.35^{b}	2.08^{ab}	1.59^{bc}	1.68	0.10^{ab}	1.35^{a}	44.04^{a}	31.98^{bc}	11.41^{a}	125.99^{abcd}	12.17^{b}	2.26^{b}	150.96^{a}	64.55^{b}	30.55^{b}	34.74^{b}
P50X2	32.02^{a}	24.75^{ab}	11.92^{b}	5.22^{a}	79.12^{b}	2.22^{b}	1.66^{c}	1.75	0.06^{ab}	1.32^{a}	52.83^{b}	32.80^{c}	11.46^{a}	125.16^{a}	13.03^{b}	2.84^{bc}	153.40^{a}	64.75^{b}	30.25^{b}	36.95^{bc}
P100X1	31.93^{a}	25.16^{ab}	11.18^{ab}	4.80^{a}	79.30^{b}	1.91^{a}	1.72^{cd}	1.69	0.06^{ab}	1.32^{a}	45.46^{a}	31.99^{bc}	11.93^{a}	125.45^{ab}	10.67^{a}	2.58^{bc}	148.76^{a}	64.34^{b}	32.30^{c}	27.63^{a}
P100X2	32.64^{a}	25.29^{ab}	11.72^{b}	5.50^{a}	78.98^{b}	2.16^{b}	1.93^{e}	1.71	0.08^{ab}	1.32^{a}	43.23^{a}	31.18^{b}	11.62^{a}	126.14^{bcd}	10.22^{a}	2.83^{bc}	148.12^{a}	63.14^{a}	31.76^{bc}	39.50^{cd}
P200X1	31.23^{a}	23.96^{a}	10.94^{ab}	5.07^{a}	79.32^{b}	2.21^{b}	1.84^{de}	1.76	0.03^{a}	1.34^{a}	44.69^{a}	31.41^{b}	11.54^{a}	126.32^{cd}	11.50^{ab}	3.03^{c}	150.29^{a}	63.65^{ab}	33.06^{c}	34.54^{b}
P200X2	32.10^{a}	26.11^{b}	10.12^{a}	4.90^{a}	78.42^{ab}	2.15^{b}	1.84^{de}	1.69	0.11^{ab}	1.23^{a}	42.52^{a}	32.22^{bc}	11.93^{a}	125.50^{abc}	10.60^{a}	2.83^{bc}	142.14^{a}	62.96^{a}	33.09^{c}	28.81^{a}
PGR *P*	**	**	**	**	**	**	**	ns	*	**	**	**	**	**	**	**	*	**	**	**
(b) Substrate																				
S	36.59$^{c\#}$	27.57^{cd}	14.66^{d}	6.20^{c}	77.92^{ab}	2.63^{c}	1.73^{b}	1.75^{cd}	0.15^{b}	1.34^{bc}	49.69^{bc}	31.71	12.63^{d}	124.67^{a}	11.77^{b}	2.26^{bc}	155.11^{cde}	63.15^{a}	32.08	36.55
SGC	23.84^{a}	22.35^{a}	6.41^{a}	2.94^{a}	77.20^{a}	1.80^{a}	1.76^{b}	2.58^{e}	0.30^{c}	1.11^{a}	27.13^{a}	32.00	12.16^{cd}	125.17^{ab}	11.54^{b}	2.96^{d}	139.43^{abc}	65.89^{c}	30.64	37.73
SP	42.43^{d}	27.11^{bcd}	15.16^{d}	7.13^{d}	79.32^{c}	2.24^{b}	1.82^{b}	1.40^{a}	0.03^{a}	1.58^{e}	54.56^{c}	30.89	11.56^{abc}	126.25^{c}	12.48^{b}	2.31^{bc}	173.44^{e}	63.73^{ab}	31.03	37.23
SCP	36.37^{c}	26.20^{bcd}	13.01^{c}	5.33^{b}	77.90^{ab}	2.20^{b}	1.70^{b}	1.58^{abc}	0.08^{ab}	1.41^{cd}	48.27^{bc}	31.36	12.02^{bcd}	125.59^{bc}	12.44^{b}	1.36^{a}	167.79^{de}	65.50^{c}	30.43	36.91
SPB	41.02^{d}	27.65^{d}	15.59^{d}	6.76^{d}	79.46^{c}	2.62^{c}	1.66^{ab}	1.50^{ab}	0.01^{a}	1.51^{de}	55.50^{c}	31.31	11.75^{abc}	125.94^{bc}	12.99^{b}	1.82^{b}	159.22^{de}	65.60^{c}	29.40	32.99
SGCP	35.33^{c}	26.11^{bc}	10.12^{b}	5.31^{b}	79.53^{c}	2.27^{b}	1.53^{a}	1.65^{bc}	0.04^{a}	1.37^{bc}	47.90^{bc}	32.10	11.29^{a}	126.25^{c}	11.77^{b}	3.01^{d}	133.44^{ab}	63.70^{ab}	31.03	34.05
SGCCP	31.94^{b}	25.78^{b}	10.26^{b}	5.00^{b}	78.50^{bc}	1.65^{a}	1.72^{b}	1.90^{d}	0.02^{a}	1.26^{b}	44.85^{b}	31.46	11.36^{ab}	126.44^{c}	10.17^{a}	2.70^{cd}	131.04^{a}	64.26^{ab}	30.84	37.03
SGCPB	36.19^{c}	26.32^{bcd}	10.42^{b}	5.31^{b}	79.17^{c}	1.86^{a}	1.65^{ab}	1.53^{abc}	0.06^{a}	1.40^{c}	44.63^{b}	31.55	11.61^{abc}	126.02^{bc}	12.08^{b}	2.79^{cd}	149.61^{bcd}	64.72^{bc}	30.40	37.09
Sub *P*	**	**	**	**	**	**	**	**	**	**	**	ns	**	**	**	**	**	**	ns	*

Table 3. to be continued

	Growth										Ornamental characteristics									
	H	Ø	LDW	BDW	SPAD	RD	RT	RC	MR	H/Ø	LN	L*L**	L*C**	L*h*°	LG	FN	FV	F*L**	F*C**	F*h*°
(c) Interactions																				
cv *P*[§]	**	**	**	**	**	*	ns	*	ns	ns	ns	**	**	**	**	**	**	**	**	**
cv-Sub *P*	**	ns	*	*	**	**	**	*	*	**	**	*	**	*	*	**	**	**	*	**
PGR-cv *P*	**	*	ns	*	*	*	ns	ns	ns	**	*	*	*	*	**	*	ns	**	**	**
PGR-Sub *P*	**	*	**	**	*	*	*	ns	*	**	*	ns	**	*	*	*	**	*	ns	**
PGR-cv-Sub *P*	**	**	ns	*	ns	*	ns	*	ns	ns	**	ns	*	ns	**	*	*	**	**	**

[#]Means followed by the same letter do not differ significantly at $P < 0.05$, according to REGW-*F* test. [§]The statistical relevance of Between-Subjects Effects' Tests (* = $P < 0.05$, ** = $P < 0.001$, ns = non-significant)

Abbreviations and symbols: H – height, Ø – diameter, LDW, BDW – leaves and branches dry weights, respectively; SPAD – chlorophyll content; RD, RT, RC – root density, thickness, color, respectively; MR – mortality rate, H/Ø – height-diameter ratio; LN, L*L**, L*C**, L*h*°, LG – leaf number, lightness, chroma, hue angle, gloss, respectively; FN, FV, F*L**, F*C**, F*h*° – flower number, volume, lightness, chroma, hue angle, respectively

lyzed for the most important growth and ornamental parameters (H, Ø, and FN; data not shown). PBZ application affected H in all media, Ø was clearly reduced in S, SCP, SPB, SGCP, and SGCCP, while FN was increased in SP, SCP, SPB, and SGCPB. Similarly, the effect of growth regulation on each cultivar was evaluated (data not shown). Differences were detected especially for height control. Generally PBZ treatments showed more effectiveness on NP while, in few cases (when camellias were grown in SP or SPB), DB showed a positive response only to treatments higher than P50X1.

Interactions among fixed factors caused difficulty in interpreting some growth regulation data. In particular, between control treatments (Table 3a), differences were detected concerning plant diameter, leaf characteristics (L*L**, L*C**, L*h*°, LG) and flower volume (FV) and color (F*h*°). Generally, in these cases, the controls gave values comparable with PBZ treatments. No differences among PBZ treatments were highlighted in H, BDW, SPAD, H/Ø, MR, FV, and L*C** while, in few cases (RT, LG, F*L**), higher dosages highly influenced growth and ornamental characteristics. For all the other parameters, PBZ effect was less clear. Basically, P50X1 can be considered as the most appropriate treatment, with a view to environmental impact and to economical context, being the lowest dosage tested to be effectively active. In fact P50X1 showed, generally, as every other PBZ treatment regime tested, a remarkable reduction of some of the most important parameters, such as height and the widest diameter and promoted the production of a higher number of flowers, with darker, more vivid and more reddish colors. Therefore, paclobutrazol dosage can be reduced drastically without affecting negatively growth control, in contrast to previous studies in which paclobutrazol was used only at high dosages (500 mg/l, Wilkinson, Richards 1988; 250–1,000 mg/l, Song, Lee 1995). Moreover, in contrast to Banko and Landon (2005), paclobutrazol treatments increased flowering. Within paclobutrazol treatments, flower color was negligibly improved by higher dosages. As for substrate influence, only SGC was inappropriate for camellia pot cultivation. Probably due to its higher salinity and pH, green compost at 30% caused phytotoxic effects and a following high mortality rate. Lower percentages of green compost in media bearing other peat alternatives (SGCP, SGCCP, SGCPB) showed less mortality compared with S and SGC, suggesting a dampening of phytotoxicity by means of pumice, coconut peat, and pine bark. In terms of growth and ornamental value, pumice, and pine bark provided the best results, promoting development, improving health and enhancing leaf production and flower quality. In detail, referring to the latter characteristic, SP particularly increased flower size while SPB stimulated production of lighter flowers. With respect to flowering, substrate containing green compost, with particular regard to SGC and SGCP, showed to increase flower production while reducing flower size. Finally, as expected and already assessed by previous studies (Corneo, Remotti 2003; Scariot et al. 2007), cultivars behaved very differently. In particular, in spite of overall mean values indicating similarity in growth related parameters, the two cultivars grew and flowered differently within the same medium, except for S and partially for SCP and SGCPB (influence of cultivar was not seen on plant height) and for SGCP (influence of cultivar was not seen on plant diameter). In this medium, a flattening of performance differences between the two cultivars was observed. This feature is desired in the pot cultivation field, where treating different cultivars as if they were one could lead to cost and time effectiveness in particular, when the flattening concerns growth and developmental differences between cultivars, such as height at the end of cultivation, flowering period, and dormancy break. Besides, a reduced effect of cultivar on plant growth regulator treatment would be very interesting from a pot cultivation process standardization point of view. Interaction between growth regulation and cultivar is visibly lowered by the standard substrate for both growth and ornamental characteristics, for example branches dry weight (BDW) and flower number (FN). However, in these cases, standard substrate seems to dampen PBZ effect, highlighting a non-clear separation among PBZ and control treatments. In some cases, interactions among cultivar, substrate and PGR could provide better performances of plants, especially for growth control and flowering enhancement. For instance, when cultivar DB was grown in SP, these interactions showed to work positively, promoting the best flowering with the lowest dosage of paclobutrazol. As shown in Table 3c, interaction between PGR and substrate are widespread to almost every parameter reported, including those directly connected to growth control and flowering promotion. That leads us to infer about the possibility of having positive plant growth regulation protocol and substrate combination, regardless of the cultivar. On the whole, an ideal combination of substrate and growth regulation protocol would consist in a substrate able to standardize plant growth within and between cultivars and not to interact with PGR application but for enhancing its activity, and in a PGR able to act equally between different cultivars.

Thus, for camellia pot cultivation, SPB resulted as the most proper substrate, in agreement with previous studies about suitability of pine-derived substrates for *Camellia* pot cultivation (Keever, McGuire 1991; Alexander 2009; Larcher, Scariot 2009). However, the choice among peat substitutes should depend also on their cost and availability. Thereby, pine bark being the most expansive peat alternative, the choice could also pertain to other substrate mixtures such as SCP, which behaved similarly to peat, corroborating another study on coir-based substrates suitability on Impatiens (Argo, Biernbaum 1996). This medium could, therefore, represent a more economical alternative, characterized by an acceptable mortality rate within all PBZ treatments. SP resulted suitable too, showing no diameter reduction but very relevant flowering in response to paclobutrazol applications, which caused no mortality. To compensate for the greater growth in pine bark and pumice based substrate, paclobutrazol concentration may need to be increased slightly to achieve a similar plant height as with the peat-based and coir-based substrate. These results are in agreement with previous studies (Million et al. 1998a, b) which showed that paclobutrazol had less activity on *Petunia* and *Dendranthema* grown in pine bark, which promoted a higher growth rate, than in peat. In conclusion, considering a standardized protocol for different cultivars, the application of paclobutrazol 50 mg/l spray combined with the use of pumice, pine bark or coconut peat, with the latter providing the less vigorous growth, is suggested. However, while in the United States paclobutrazol is registered for use at EPA (Environmental Protection Agency), in some EU member states this molecule has recently been revoked. Therefore, studies on alternatives to paclobutrazol and, in general, to chemical control, are needed.

Acknowledgements

The authors wish to thank Fiori Tipici del Lago Maggiore s.c.r.l. and Tecnoverde s.p.a. (VB) for technical support; Renzo Bizioli and Gianni Morandi for their assistance in the experimental work; Ce.R.S.A.A. of Savona for their assistance in physico-chemical and biological analyses; Agrimedia and Cooperativa Sociale Risorse (VB) for providing substrates and the entire staff of the Floriculture group of the Turin University for their support with surveys.

References

Alexander P., 2009. Replacing peat in ericaceous growing media. The Plantsman, *8*: 226–229.

Argo W.R., Biernbaum J.A., 1996. Component comparisons: coconut coir. GrowerTalks, *59*: 62–66.

Bailey D.A., Whipker B.E., 1998. Height control of commercial greenhouse flowers. NC State University Horticulture Information Leaflets, 528. Available at: www.ces.ncsu.edu/depts/hort/floriculture

Bailey D.A., 1991. Chemical growth retardants for bedding plants. NC Flower Growers' Bullettin, *36*: 1–6.

Banko T.J., Landon A.L., 2005. Sumagic (uniconazole) promotes flower bud set on *Camellia japonica*. Journal of Environmental Horticulture, *23*: 153–157.

Brown R.G., Kawaide S.H., Yang Y.Y., Rademacher W., Kamiya Y., 1997. Daminozide and prohexadione have similar modes of action as inhibitors of the late stages of gibberellin metabolism. Physiologia Plantarum, *101*: 309–313.

Corneo A., Remotti D., 2003. Camelie dell'Ottocento nel Verbano. Torino, Italy, Regione Piemonte: 261.

Davis T.D., Andersen A., 1989. Growth retardants as aids in adapting new floricultural crops to pot culture. Acta Horticulturae, *252*: 77–86.

Di Benedetto A., Molinari J., 2007. Influence of river waste-based media on efficacy of paclobutrazol in inhibiting growth of *Petunia* × *hybrida*. International Journal of Agricultural Research, *2*: 289–295.

Halevy A.H., 1983. Regulation of flowering in flower crops by growth substances. Acta Horticulturae, *147*: 193–198.

Hernández-Apaolaza L., Gascó A.M., Gascó J.M., Guerrero F., 2005. Reuse of waste materials as growing media for ornamental plants. Bioresource Technology, *96*: 125–131.

Keever G.J., McGuire J.A., 1991. Sumagic (uniconazole) enhances flowering of 'Shishi-Gashira' camellia. Journal of Environmental Horticulture, *9*: 185–187.

Latimer J.G., 1998. Mechanical conditioning to control height. HortTechnology, *8*: 529–534.

Larcher F., Scariot V., 2009. Assessment of partial peat substitutes for the production of *Camellia japonica*. HortScience, *44*: 312–316.

Meijon M., Rodriguez R., Canal M.J., Feito I., 2009. Improvement of compactness and floral quality in azalea by means of application of plant growth regulators. Scientia Horticulturae, *119*: 169–176.

Million J.B., Barrett J.E., Nell T.A., Clark D.G., 1998a. Influence of media components on efficacy of paclobutrazol in inhibiting growth of broccoli and petunia. HortScience, *33*: 852–856.

Million J.B., Barrett J.E., Nell T.A., Clark D.G., 1998b. Influence of pine bark on the efficacy of different growth retardants applied as a drench. HortScience, *33*: 1030–1031.

Moe R., Heins R.D., Erwin J., 1991. Stem elongation and flowering of the long-day plant *Campanula isophylla* Moretti in response to day and night temperature alternations and light quality. Scientia Horticulturae, *48*: 141–151.

Myster J., Moe R., 1995. Effect of diurnal temperature alternations on plant morphology in some greenhouse crops: a mini review. Scientia Horticulturae, *62*: 205–215.

Onozaki T., Mato M., Shibata M., Ikeda H., 1999. Differences in flower color and pigment composition among white cornation (*Dianthus caryophyllus* L.) cultivars. Scientia Horticulturae, *82*: 103–111.

Rademacher W., 1989. Gibberellins: metabolic pathways and inhibitors of biosynthesis. In: Boger P., Sandmann G., (ed.), Target Sites of Herbicide Action. Boca Raton, Florida, USA, CRC Press: 127–146.

Rademacher W., 1992. Inhibition of gibberellin production by plant growth retardants in the fungi *Gibberella fujikuroi* and *Sphaceloma manihoticola*. Plant Physiology, *100*: 625–629.

Ribeiro H., Romero A.M., Pereira H., Borges P., Cabral F., Vasconcelos E., 2007. Evaluation of a compost obtained from forestry wastes and solid phase of pig slurry as a substrate for seedlings production. Bioresource Technology, *98*: 3294–3297.

Smith B.R., Fisher P.R., Argo W.R., 2004. Growth and pigment content of container-grown *Impatiens* and *Petunia* in relation to root substrate pH and applied micronutrient concentration. HortScience, *39*: 1421–1425.

Song C.Y., Lee J.S., 1995. Effect of growth regulators on growth and flowering of potted camellia. Journal of the Korean Society for Horticultural Science, *36*: 98–106.

Scariot V., Lombardo D.M., Merlo F., 2007. Camelie dell'Ottocento vol. II. Uno studio tra Verbano e Canton Ticino. Torino, Italy, Regione Piemonte: 183.

Torre S., Moe R., 1998. Temperature, DIF and photoperiod effects on the rhythm and rate of stem elongation in *Campanula isophylla* Moretti. Scientia Horticulturae, *72*: 123–133.

Whipker B.E., Gibson J.L., Cavins T.J., 2001. Diagnosing problems due to Plant Growth Regulators. NC State University Floriculture Research FlorRx, 001. Available at: www.ces.ncsu.edu/depts/hort/floriculture

Wilkinson R.I., Richards D., 1988. Influence of paclobutrazol on the growth and flowering of *Camellia* × *Williamsii*. HortScience, *23*: 359–360.

Received for publication July 23, 2010
Accepted after corrections November 2, 2010

Corresponding author:

Federica Larcher, University of Turin, Faculty of Agriculture, Department of Agronomy, Forest and Land management, Via Leonardo da Vinci, 44 – 10095 Grugliasco, Turin, Italy
phone: + 39 011 670 8793, fax: + 39 011 670 8798, e-mail: federica.larcher@unito.it