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Evaluation of Alternative Substrates for Bedding Plants

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Abstract: The aim of the present study was to investigate the effects of some locally produced alternative substrates (River Waste-and Argentinean peat-base) on the growth of three bedding annual plants. Results showed that it is possible to obtain high quality *Viola wittrokiana*, *Petunia x hybrida* and *Impatiens wallerana* plants grown in a soilless media containing Argentinean (*Sphagnum* and *Carex*) peat (a material from younger weatlands) and river waste, but the most new growing media can not be analyzed through the conventional methods of analysis used for peat-based media and a new analytical approach is demanding. The effect of changes in dry weight gain, root:shoot ratio, root length and leaf area developed on grower returns and post-sale behavior are discussed.

Key words: Growing media, nursery, ornamental plant, peat, river waste

Introduction

Growing media or components for potting soil mixes are very important production factors in horticulture. Most of the ornamental crops produced in glasshouses are growing in artificial growing media. Those growing media are usually made up of several components. They are a very important production feature and choosing the right media to grow quality bedding plants is a key factor in crop production. That is why industries and trade companies are very active on the market of growing media and research supports them.

The most common substrate for such cultures is based on *Sphagnum* peat, due to its high physical and chemical stability and low degradation rate. The increasing cost of high quality peat for horticultural use, together with the declining availability of peat in the near future due to environmental constraints (Frolking *et al*., 2001; Schilstra, 2001), especially to look for alternative materials (Abad *et al*., 2001; Guerin *et al*., 2001; García-Gomez *et al*., 2002).

In areas lacking indigenous peat deposits and where imported peat is expensive, it is common for potting media to contain high proportions of wood wastes (Chong and Cline, 1993; Kuehny and Morales, 1998) such as aged or composted barks and composted sawdust (Burger *et al*., 1997; Manning *et al*., 1995; Menzies and Aitken, 1996) and/or a whole range of waste materials such as rice hulls (Papafotiou *et al*., 2001a, b), ground coconut husks (De Kreij and Van Leeuwen, 2001; Abad *et al*., 2002) and composted municipal or industrial solid wastes (Chong, 1999; Zubillaga and Lavado, 2001).

The presence of wetland ecosystems in the South of Argentina (15,300,000 ton of *Carex* and *Sphagnum* peat) offers a potential substitute for Canadian peat; however, there is no research so far to support it and previous results have indicated troubles when it was used for annual bedding plants (Di Benedetto *et al*., 2006).

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For some time, river waste was used as a locally available material for preparing soilless growing media for containerized crop production. Only during the past few years has this material become commercially popular and it is now being successfully sound peat substitute for container-grown ornamental plants. It has been successfully tested as a growing medium for perennial pot plants (Di Benedetto *et al*., 2004) but its availability as a media for bedding plants was not yet investigated.

Alternative substrates, that are well characterized and corrected by suitable mixtures, would make it possible to produce plants with a better quality, more rapidly (Calkins *et al*., 1997) and avoid the over-exploitation of natural peatlands. The characterization of materials used as container media for soilless substrate culture must take into account their physical, chemical and biological properties. The present study would be essential because substrate properties are limiting factors that can affect the size of the container used, irrigation scheduling and feeding program (Noguera *et al*., 2003). But, the use of alternative substrates requires knowledge of new characteristics for mixing and also for offering best conditions to plant growth during the culture.

The aim of this research was to study the effects of some locally produced alternative substrates (River Waste-and Argentinean peat-base) on the growth of three bedding annual plants.

Materials and Methods

Thirteen substrates were formulated using river waste, Argentinean *Sphagnun* and *Carex* peat, rice hull, perlite and vermiculite. A commercial media high quality peat-base (Fafard Growing Mix 2®) (Canadian *Sphagnum* peat moss-perlite-vermiculite 70:20:10 v/v) as a control was used. The formulae (v/v) were:

- Fafard Growing Mix 2® (100%)(F)
- *Sphagnum* peat (80%)+Vermiculite (10%)+Perlite (10%)(S_{80})
- *Carex* peat (80%)+Vermiculite (10%)+Perlite (10%)(C_{80})
- *Sphagnum* peat (40%)+*Carex* peat (40%)+Vermiculite (10%)+Perlite (10%) ($S_{40}C_{40}$)
- River Waste (80%)+Vermiculite (10%)+Perlite (10%)(RW_{80})
- *Sphagnum* peat (80%)+River Waste (20%)($S_{80}RW_{20}$)
- *Carex* peat (80%)+River Waste (20%)($C_{80}RW_{20}$)
- *Sphagnum* peat (40%)+*Carex* peat (40%)+River Waste (20%)($S_{40}C_{40}RW_{20}$)
- *Sphagnum* peat (50%)+River Waste (50%)($S_{50}RW_{50}$)
- *Carex* peat (50%)+River Waste (50%)($C_{50}R_{50}$)
- *Sphagnum* peat (25%)+*Carex* peat (25%)+River Waste (50%)($S_{25}C_{25}R_{50}$)
- *Sphagnum* peat (40%)+River Waste (40%)+Rice Hull (20%)($S_{40}RW_{40}RH_{20}$)
- *Carex* peat (40%)+River Waste (40%)+Rice Hull (20%)($C_{40}RW_{40}RH_{20}$)
- *Sphagnum* peat (20%)+*Carex* peat (20%)+River Waste (40%)+Rice Hull (20%)($S_{20}C_{20}R_{40}CA_{20}$)

A weekly fertilization of 100 ppm N (1N:0.5 P:1K:0.5 Ca v/v) from transplant to sale stages were used. All nitrogen was as nitrates and a fertilization volume of 100 mL pot^{-1} was applied. Plants were irrigated with a high quality tap water (pH: 6.64 and electrical conductivity of 0.486 dS m^{-1}).

Viola wittrokiana Saint Tropez, *Petunia x hybrida* Ultra and *Impatiens wallerana* Accent seeds were germinated and grown in 200 plastic plug trays at greenhouse facilities from Buenos Aires University campus, Argentina (34°28'S). A Fafard Growing Mix® as a growing media was used. When the fourth true leaf was developed 20 plants were transplanted into 1,000 cm^{-3} pots containing the different soilless media tested.

Samples of each medium were collected at transplanting and at the end of the experiment and physical properties were determined according to the methodology suggested by Fonteno (1996). This procedure requires to fill a container of known volume with the substrate. The standard pot used had holes in the bottom that were tape-closed and covered on the inside by nylon screens. The volume of substrate was recorded and water was added slowly until the substrate was saturated to the surface and the volume of added water was registered. The tape from the bottom of the container was then removed and the drained water was collected for 60 minutes. The wet sample was weighed, then dried and reweighed.

The values obtained from the earlier procedures were used to calculate total porosity, air-filled porosity, bulk density and container capacity using the following equations:

$$\text{Total porosity (\%v/v)} = \frac{\text{(wet weight-dry weight)+drained volume}\times 100}{\text{substrate volume}}$$

$$\text{Air-filled porosity (\%v/v)} = \frac{\text{drained volume}\times 100}{\text{substrate volume}}$$

$$\text{Bulk density (g cm}^{-3}) = \frac{\text{dry weight}\times 100}{\text{substrate volume}}$$

$$\text{Container capacity (\%v/v)} = \frac{\text{(wet weight-dry weight)}\times 100}{\text{substrate volume}}$$

Chemical properties such as pH, Electrical Conductivity (EC), Organic Matter (OM) and nutrient concentrations were determined on all substrates at transplanting using standard procedures (Sparks *et al*., 1996). Electrical conductivity and pH were recorded at the end of the experiments too. Most analyses were performed by triplicate.

Crops were harvested, dried at 80°C for 48 h and weighed to obtain the dry aerial and root biomass weight. Data were subjected to a one way ANOVA for a completely randomized design analysis and means were statistically checked by Tukey tests ($p<0.05$).

Results

Chemical properties of the alternative components are shown in Table 1. Argentinean peat (*Sphagnum* and *Carex*) and River Waste would require a pH adjust (to a value near 5.8). Electrical conductivity was low except for River Waste (2.02 dS m^{-1}). The lowest organic matter percentages

Table 1: Chemical properties of the alternatives components of the growing media tested. Each value is the mean of three replicates

	pH	EC (dS m^{-1})	OM (%)	N total (%)	P (ppm)	(meq/100 g) K	Ca	Mg	Na	CEC
S	4.80	0.11	94.24	0.90	5.26	0.78	12.18	1.98	0.21	24.05
C	4.51	0.56	90.44	1.13	92.05	0.44	15.22	1.50	0.86	26.50
RW	5.15	2.02	69.92	1.14	9.74	1.05	26.40	2.32	2.24	41.00
RH	6.77	0.48	88.53	0.65	25.41	1.12	15.97	1.34	0.71	25.03
F	6.06	1.14	81.07	1.71	4.57	1.02	22.11	4.19	1.03	36.70

EC: Electrical Conductivity; OM: Organic Mater; N: Nitrogen; P: Phosphorus; K: Potassium; Ca: Calcium; Mg: Magnesium; Na: Sodium; CEC: Cation Exchange Capacity; S: Sphagnum peat, C: Carex peat, RW: River Waste, RH: Rice Hull, F: Fafard Growing Mix 2®

Table 2: Changes in the chemical properties from the growing media tested between the beginning and the end of the experiments. Each value is the mean of three replicates

	pH				Electric conductivity (dS m^{-1})			
		End				End		
	Initial	*Viola*	*Petunia*	*Impatiens*	Initial	*Viola*	*Petunia*	*Impatiens*
F	5.85	6.50	6.34	6.29	0.528	0.714	0.776	1.100
S_{80}	5.85	6.56	6.16	6.40	0.057	0.552	0.533	0.743
Ca_{80}	5.99	6.75	6.55	6.47	0.186	0.714	0.681	0.976
$S_{40}C_{40}$	6.01	6.71	6.55	6.11	0.071	0.614	0.614	0.848
R_{80}	6.13	6.15	6.13	6.09	0.329	0.489	0.671	1.247
$C_{80}R_{20}$	6.27	6.01	5.69	5.33	0.143	0.448	0.376	0.605
$C_{80}R_{20}$	6.28	6.18	5.89	5.43	0.286	0.571	0.476	0.881
$S_{40}C_{40}R_{20}$	6.28	6.14	5.81	5.18	0.171	0.500	0.419	0.800
$S_{50}R_{50}$	6.29	6.04	5.72	5.26	0.286	0.519	0.400	0.829
$C_{50}R_{50}$	6.30	6.14	5.86	5.93	0.286	0.619	0.548	0.881
$S_{25}C_{25}R_{50}$	6.31	6.09	5.80	5.87	0.243	0.629	0.500	0.957
$S_{40}R_{40}CA_{20}$	6.27	6.15	5.73	5.81	0.286	0.533	0.429	0.781
$C_{40}R_{40}CA_{20}$	6.28	6.19	5.89	6.05	0.300	0.586	0.481	0.895
$S_{20}C_{20}R_{40}CA_{20}$	6.27	5.95	5.88	6.01	0.314	0.422	0.486	0.867

S: Sphagnum peat, C: Carex peat, RW: River Waste, RH: Rice Hull, F: Fafard Growing Mix 2®

Table 3: Changes in the physical properties from the growing media tested between the beginning and the end of the experiments. Each value is the mean of three replicates

	Porosity (%)				Air-filled porosity (%)			
		End				End		
	Initial	*Viola*	*Petunia*	*Impatiens*	Initial	*Viola*	*Petunia*	*Impatiens*
F	85.72	72.80	85.00	81.78	20.94	22.27	18.53	27.44
S_{80}	85.50	70.87	73.07	69.17	15.94	20.60	20.40	18.56
Ca_{80}	78.56	70.93	62.27	76.22	17.00	18.07	15.53	24.17
$S_{40}C_{40}$	86.22	70.70	69.33	67.11	19.89	21.60	18.33	13.56
R_{80}	62.83	66.07	95.20	65.89	14.56	18.93	21.73	18.61
$C_{80}R_{20}$	57.44	68.60	72.13	62.50	11.06	13.47	23.73	20.06
$C_{80}R_{20}$	75.67	76.47	73.40	71.61	15.11	14.93	18.93	16.39
$S_{40}C_{40}R_{20}$	67.44	71.93	73.33	64.89	18.89	24.00	22.33	14.39
$S_{50}R_{50}$	63.50	71.27	76.87	79.44	17.06	12.27	19.33	19.00
$C_{50}R_{50}$	60.06	66.67	72.67	71.50	16.67	20.00	19.53	17.89
$S_{25}C_{25}R_{50}$	60.56	68.60	73.33	61.61	15.94	16.60	17.53	13.72
$S_{40}R_{40}CA_{20}$	55.67	74.40	73.27	60.17	18.22	21.60	18.40	15.67
$C_{40}R_{40}CA_{20}$	57.56	73.67	72.60	61.78	17.17	20.47	19.20	19.08
$S_{20}C_{20}R_{40}CA_{20}$	56.78	67.15	72.27	63.50	16.22	20.42	19.27	19.72

	Container capacity (%)				Bulk density (g cm^{-3})			
		End				End		
	Initial	*Viola*	*Petunia*	*Impatiens*	Initial	*Viola*	*Petunia*	*Impatiens*
F	22.78	25.33	20.67	28.61	0.14	0.30	0.14	0.17
S_{80}	25.94	23.67	22.00	20.28	0.18	0.40	0.18	0.36
Ca_{80}	23.00	28.67	20.67	24.17	0.23	0.33	0.23	0.26
$S_{40}C_{40}$	20.89	24.67	21.00	14.72	0.19	0.39	0.19	0.30
R_{80}	15.56	21.33	23.33	19.44	0.55	0.48	0.55	0.46
$C_{80}R_{20}$	17.06	21.33	27.33	19.72	0.22	0.45	0.22	0.30
$C_{80}R_{20}$	17.11	29.00	25.33	16.67	0.29	0.37	0.29	0.28
$S_{40}C_{40}R_{20}$	10.89	27.33	23.33	25.00	0.27	0.41	0.27	0.29
$S_{50}R_{50}$	10.06	23.67	20.67	20.00	0.35	0.47	0.35	0.23
$C_{50}R_{50}$	18.67	23.67	22.33	19.17	0.36	0.43	0.36	0.29
$S_{25}C_{25}R_{50}$	11.94	26.67	20.00	15.56	0.33	0.45	0.33	0.32
$S_{40}R_{40}CA_{20}$	19.22	24.67	20.67	18.89	0.41	0.41	0.41	0.34
$C_{40}R_{40}CA_{20}$	16.17	25.67	22.33	24.17	0.37	0.42	0.37	0.34
$S_{20}C_{20}R_{40}CA_{20}$	18.22	20.55	21.67	23.33	0.44	0.42	0.44	0.36

S: Sphagnum peat, C: Carex peat, RW: River Waste, RH: Rice Hull, F: Fafard Growing Mix 2®

for River Waste were found. Nutrient concentrations were quite different according the alternative components used. Fafard Growing Mix 2® showed an 1:2.67:0.60:12.9:1.45 ratio for N: P: K: Ca: Mg, respectively; *Carex* peat and River Waste had got higher phosphorus concentrations while River Waste and Rice Hull showed the highest calcium proportions.

There were little changes in pH values and an increase in electric conductivity from the beginning at the end of the experiments for *Viola wittrokiana*, *Petunia x hybrida* and *Impatiens wallerana* plants grown under different alternative substrates (Table 2).

Substrates physical properties are shown in Table 3. Initial total porosity was significantly higher on substrates with the highest proportion of *Sphagnum* peat. However, at the end of experiments, there were only minor porosity differences between growing media. The highest initial air-filled porosity for Fafard Growing Mix 2® was found; at the end of the experiments the most alternative substrates increased it, but there was a different pattern according the plant material used. Although container capacity percentages were quiet different at the beginning of the experiments there was only

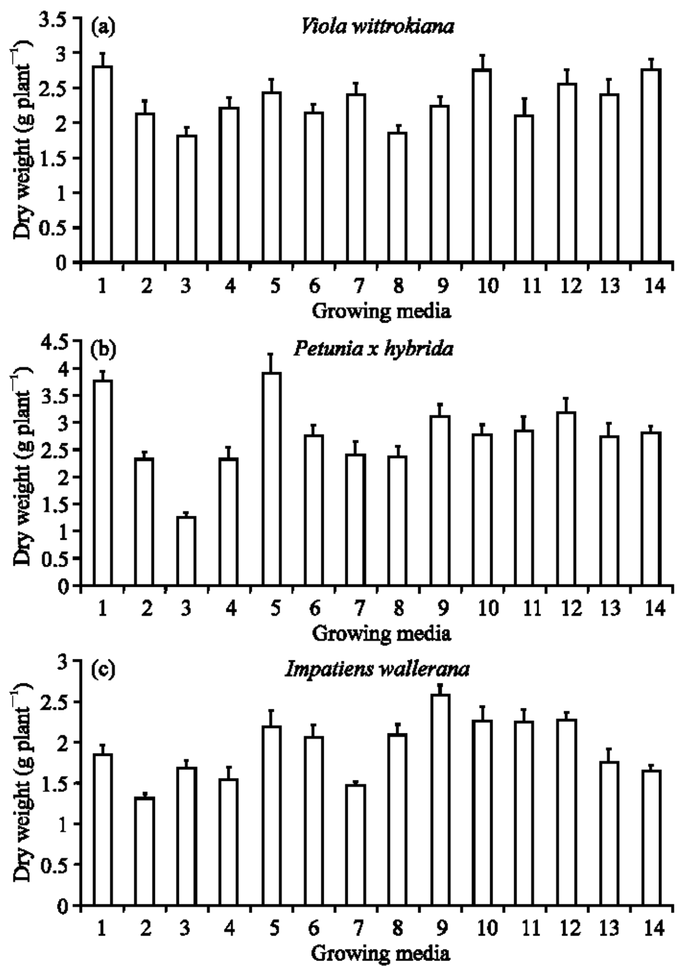

Fig. 1: The effect of different growing media on dry weight gain for three bedding plants. Bars are mean of twenty replicates and standard errors are indicated

minor differences at the end of it (especially when *Viola wittrokiana* and *Petunia x hybrida* were tested). The highest initial bulk densities were found when river waste was used, but differences decreased at the end of the experiments.

Total dry weight was related both plant material and growing media (Fig. 1) with the highest values for *Petunia x hybrida* and the lowest for *Impatiens wallerana*. There was little but significant differences for *Viola wittrokiana* (Fig. 1a) between the growing media tested. *Petunia x hybrida* (Fig. 1b) showed the highest carbon gain for the control Fafard Growing Mix 2® and RW_{80} medium. *Impatiens wallerana* showed lower dry matter accumulation for Fafard Growing Mix 2® with highest or similar values for the rest of the media tested (Fig. 1c).

The most of the growing media evaluated in the experiments showed similar or highest root:shoot ratio than the control (Fafard Growing Mix 2®) for *Viola wittrokiana* (Fig. 2a) and *Petunia x hybrida* (Fig. 2b). There were lower root:shoot ratios for *Impatiens wallerana* growing media 8 ($S_{40}C_{40}RW_{20}$), 9 ($S_{50}RW_{50}$), 10 ($C_{50}R_{50}$), 11 ($S_{25}C_{25}R_{50}$) and 12 ($S_{40}RW_{40}RH_{20}$) (Fig. 2c).

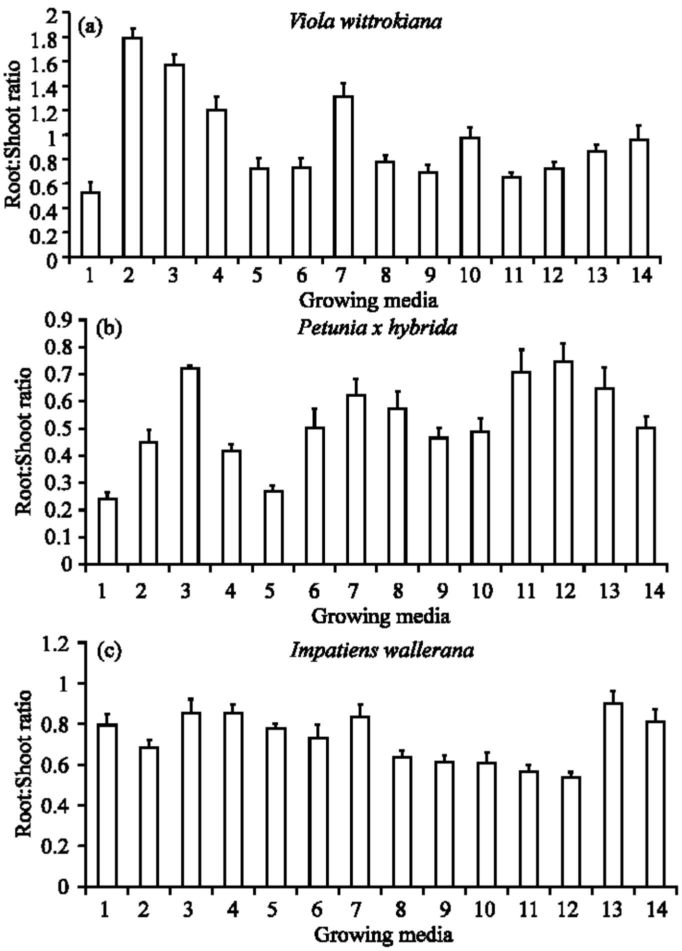

Fig. 2: Root:shoot ratio for three bedding plants grown under different growing media. Bars are mean of twenty replicates and standard errors are indicated

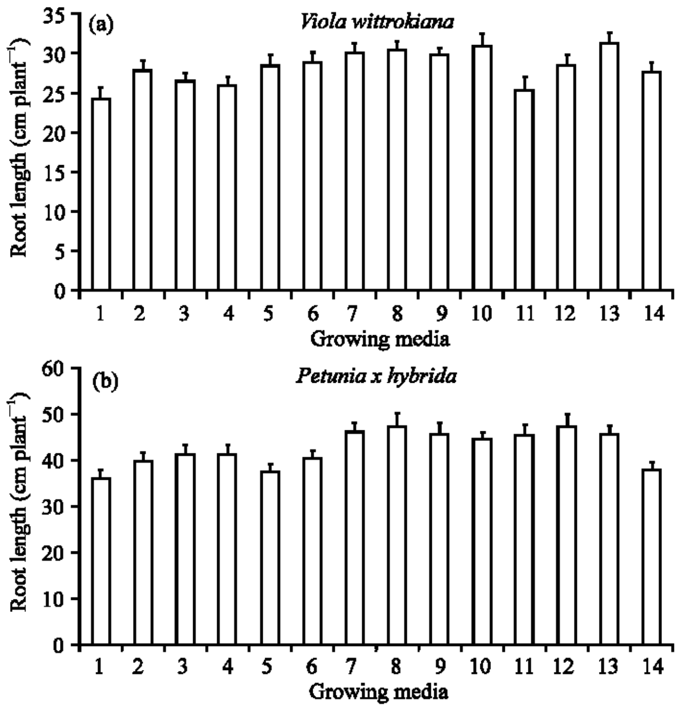

Fig. 3: Changes in root length for *Viola wittrokiana* (a) and *Petunia x hybrida* (b) grown under alternative growing media. Bars are mean of twenty replicates and standard errors are indicated

There was a significant higher root length for *Viola wittrokiana* (Fig. 3A) and *Petunia x hybrida* (Fig. 3B) when the most growing media tested were related to the control (Fafard Growing Mix 2®).

Fafard Growing Mix 2® (1) expanded a highest total leaf area than the rest of the growing media for *Viola wittrokiana* Saint Tropez (Fig. 4a) while significant higher differences behalf growing media 5 (RW_{80}), 6 ($S_{80}RW_{20}$), 8 ($S_{40}C_{40}RW_{20}$), 9 ($S_{50}RW_{50}$), 10 ($C_{50}R_{50}$) and 11 ($S_{25}C_{25}R_{50}$) was found for *Impatiens wallerana* (Fig. 4b).

Discussion

Developing peat alternative substrate is necessary for different reasons: the resources of peat are limited and the pressure for economic necessity of uses locally products increases rapidly. For bedding pot plant production, growing media needs to support growth from the time of transplant to the time to sale. Stability of the physical properties of substrates would be of primary concern because changes in these properties may negatively affect plant growth. Substrate quality and stability are related to physical attributes such as particle-size, pore-size distribution and arrangement, which influence water and gas storage and exchange properties. It is generally believed that properties of substrates initially considered appropriate for plant growth may deteriorate upon ageing due to several processes. The results of present study showed significant differences between growing media formulated from Argentinean peat-and River Waste-base related to a high quality Canadian peat-base (Fafard Growing Mix®) (Table 3).

If we take into account the ideal substrate suggested by Abad *et al*. (2001) which indicates: pH = 5.2-6.3; EC (dS m^{-1}) = 0.75-3.49; OM (%) >80; NO_3^--N (μg mL^{-1}) = 100-199; K^+ (μg mL^{-1}) = 150-249; Na^+ (μg mL^{-1}) = <115; Cl-(μg mL^{-1}) = <180; SO_4^{2-}-S (μg mL^{-1}) = <960,

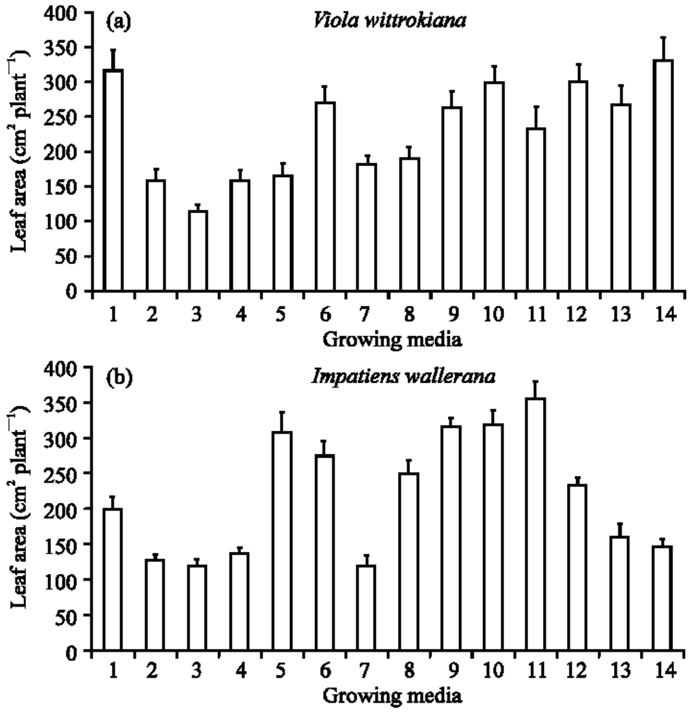

Fig. 4: Leaf area developed for *Viola wittrokiana* (a) and *Impatiens wallerana* (b) plants in response to alternative substrates. Bars are mean of twenty replicates and standard errors are indicated

the alternative growing media tested in our experiments will be excluded from this profile (Table 1 and 2).

By the other hand, the use of peat-substitute based substrate gives, at the moment, worse results (Guerin *et al*., 2001; Di Benedetto *et al*., 2006). However, present results showed that it is possible to obtain high quality *Viola wittrokiana*, *Petunia x hybrida* and *Impatiens wallerana* plants grown in a soilless media containing Argentinean (*Sphagnum* and *Carex*) peat (a material from younger weatlands) and river waste (Fig. 1), These results are in agreement with previous reports (Di Benedetto *et al*., 2004) and would confirm the suggestion made by Verghagen (1997): different physical appearance and application in horticulture is demanding a new analytical approach.

The use of rice hull in this work would be indicated as a substitute for perlite and vermiculite which increased aeration and drainage properties from *Sphagnum* and river waste base-media. However, water frequency would be increased when rice hull was used (data not shown). There is limited information (Einert and Baker, 1973; Papafotiou *et al*., 2001b) on the availability of rice hulls as a growing medium component for ornamentals and critical experiments are lacking.

Plant growth is related to both photoassimilate gain and partitioning between different organs such as roots and shoots and affect post-sale adaptation for most bedding plants. *Petunia x hybrida* dry weight gain was highly sensitive to a change of a commercial growing media from alternative substrates while *Impatiens wallerana* gave better results from most of substrate tested in the present study (Fig. 1). This is in agreement with the possibility to grow plants with the same or high quality than with commercial growing media such as Fafard Growing Mix 2®.

Bedding pot plants are sold when leaf area covers the pot and then are transplanted to field environments. The use of some of the alternative substrates tested could decrease growth cycles and labor costs for *Impatiens wallerana* (Fig. 4b). By other hand, a lower growing media cost would balance the longer growth cycles for *Viola wittrokiana* (Fig. 4a).

Plant quality at the transplant stage is related to plant biomass and photosynthetically active area. The higher total leaf area and dry weight would allow optimizing post-transplant growth. Low root:shoot ratio let short cycles with high leaf growth rates. But, if the root:shoot ratio are low when it is transplanted to field, the reserves available are invested to new roots and could deplete temporarily leaf expansion rate. On the contrary, at lower root:shoot ratio and higher root length such as some alternatives substrates tested for *Viola wittrokiana* and *Petunia x hybrida* (Fig. 2 and 3) possibilities to a rapid growth and establishment after transplant increases (Di Benedetto and Klasman, 2004).

Finally, we could stated that there were different Canadian *Sphagnum* peat amendment potentially available such as river waste and Argentinean peat for bedding plant production. But the use of its alternatives with and without rice hull (a potentially perlite-vermiculite substitute) require to reformulate management technology which include irrigation, fertilization and growth retardant chemicals which is calibrated mainly for high quality *Sphagnum* peat and physiological support on the growth processes as was indicated in the present study. The precise combination of alternative substrates in final media mix and physiological response mechanism for different plants are lacking. Calibration of crop technology for pot plants grown in a specific media mix different to *Sphagnum* peat is far (Di Benedetto and Klasman, 2007) and the subject for intense future research.

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