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The Possibilities of River Waste and Argentinean Peat as a Plug Growing Media for *Verbena* x *hybrida*.*

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Abstract: The aim of this research was to study the effects of the locally produced alternative substrates based on either river waste or Argentinean peat on germination and early growth of *Verbena x hybrida* in a plug production system. High and significant correlation coefficients between leaf area and initial pH, final electrical conductivity and final air-filled porosity were found. Root dry weight was adjusted better when related to initial electrical conductivity, initial porosity, final porosity and final air-filled porosity. The results indicate that river waste, Argentinean peat and rice hull are potentially substitute for Canadian *Sphagnum* peat in *Verbena x hybrida* plug production.

Key words: Growing media, nursery, ornamental plant, peat, river waste, *Verbena* sp.

Introduction

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 substrates are prepared with the Northern Hemisphere *Sphagnum* peat, among other reasons due to its high physical and chemical stability and low degradation rate. *Sphagnum* peat has been the most desirable component available for growing media due to high porosity, water holding capacity and cation exchange capacity (Styer and Koranski, 1997). However, the cost of high quality peat, together with its declining availability in the near future, due to environmental constraints (Frolking *et al*., 2001; Schilstra, 2001) lead to increasing needs for alternative materials (Abad *et al*., 2001; Guerin *et al*., 2001; García-Gomez *et al*., 2002). In production areas lacking local peat deposits or where imported peat is expensive, it is common to use substitutes for potting media. They are 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).

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The characterization of such materials for soilless substrate culture must take into account their physical, chemical, and biological properties. This study is 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). When those alternative substrates are well characterized and corrected by suitable mixtures, it is possible to produce plants rapidly with a good quality (Calkins *et al*., 1997), avoiding the over-exploitation of natural peatlands.

Besides the above substitute materials, Argentina has two other resources: *Carex* and *Sphagnum* peat found in high latitude ecosystems of the cold wetlands of Southern South America. This *Sphagnum* peat (henceforth referred to as Argentinean peat) is almost unique and a potential substitute for Northern Hemisphere peat, but there is no research so far to support it, although a previous report, however, has indicated problems when it was used for pot annual bedding plants (Di Benedetto *et al*., 2006). The other material is found in other countries: a kind of reed and sedge peat called locally river waste. It was used locally for preparing soilless growing media for containerized crop production. But only during the past few years has this material become commercially popular, and it is now being a successful peat substitute for container-grown ornamental plants. It has been successfully tested as a growing medium for perennial pot plants (Di Benedetto *et al*., 2004a), but its quality as a propagation medium has not yet been investigated.

Perlite and vermiculite are mineral components which increased aeration and drainage properties on *Sphagnum* peat based-media. On the other hand, rice hull are indicated as a substitute for those components. However, 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.

The aim of this research was to study the possibilities of these two local alternative substrates (river waste and *Carex* and *Sphagnum* peat) on the growth of *Verbena x hybrida* at the stage of plug production system.

Materials and Methods

Verbena x hybrida Quartz Series (Goldsmith Ind., USA) was chosen for this study based on their importance to the perennial plant industry. Seeds were germinated and grown in 72 plug trays (40.26 cm^3 $plug^{-1}$) from middle spring to summer (2004) at greenhouse facilities from Buenos Aires University campus, Argentina (34°28´S). Plug production stages considered in this study were (according to Styer and Koranski, 1997): Stage 2: after the radicle emerge and penetrate the soil; the stem (hypocotyl) and seed leaves (cotyledons) emerge; Stage 3: the true leaves grow and develop and Stage 4: seedling are ready for shipping, transplanting or holding. Plants were top irrigated with a high quality tap water.

Twenty plants were harvested for each stage of plug production and biomass was obtained drying at 80°C for 48 h and weighed.
Treatments were:

RW: River Waste alone
RW_{RH}: River Waste - Rice Hulls (70/30 v/v)
RW_{P+V}: River Waste - Perlite - Vermiculite (70/20/10 v/v)
AP: Argentinean peat alone
AP_{RH}: Argentinean peat - Rice Hulls (70/30 v/v)
AP_{P+V}: Argentinean peat - Perlite - Vermiculite (70/20/10 v/v)
CP_{P+V}: Canadian peat - Perlite - Vermiculite (70/20/10 v/v)

Table 1: Chemical and physical properties for the River waste and peat sources tested

	River waste	Argentinean peat	Canadian peat
Organic matter (%)	87.09	82.32	97.9
pH	5.5	3.6	3.8
Electrical conductivity (dS m^{-1})	1.14	0.22	0.32
N (%)	0.93	0.84	1.21
P (mg L^{-1})	8.63	3.56	4.57
K (mg L^{-1})	262.7	501.2	198.3
Ca (mg L^{-1})	427.5	788.0	100.5
Mg (mg L^{-1})	318.6	239.5	13.0
Na (mg L^{-1})	344.7	145.6	40.6
Total porosity (%)	62.8	83.2	88.1
Air-filled porosity (%)	14.6	20.0	21.2

Chemical characteristics for River Waste, Argentinean and Canadian peat are reported in Table 1. pH values were adjusted to 5.8 units using dolomite.

Five samples of each medium were collected before the transplant (initial) and at the end of stage 4 (transplant). Total porosity was determined using the following equation:

$$\text{Total porosity (\%)} = 100\,(1\text{-}A_d/B_d) \tag{1}$$

Where A_d: Particle density, determined using a picnometer.
B_d: Bulk density

Total porosity and air-filled porosity were determined using standard methods (Flint and Flint, 2002). Chemical properties (ph and electric conductivity) were determined too.

Analysis of variance was performed on a incomplete factorial-split and means were separated by Tukey test ($p \le 0.01$ or 0.05).

Results

At the beginning of the experiment there were significant differences in total porosity (Table 2). Argentinean p alone (AP) showed the lower porosity values. Rice hulls mixed with river waste and Argentinean peat (RW_{RH} and AP_{RH}) give the best results. This mixes maintained the differences in total porosity at the end of the experiment as compared with the rest of the treatments: Even more than a Canadian peat-base media (CP_{P+V}), included as a check. Electrical conductivity and pH at the start and the end of the experiment practically did not show differences among mixes tested (Table 3).

Table 2: Total porosity (%) for the media tested. Values are means of five samples

	Total porosity (%)	
	Initial	End
RW	72.4bc	70.0b
RW_{RH}	77.8a	76.2a
RW_{P+V}	71.6c	69.2b
AP	62.4e	58.8d
AP_{RH}	78.2a	76.0a
AP_{P+V}	68.2d	65.0c
CP_{P+V}	74.4b	72.0b

Different lower case letter (s) indicate statistically differences ($p \le 0.01$) between treatments

Table 3: Electrical conductivity (dS m^{-1}) and pH for the media tested. Values are mean of five samples

	Electrical conductivity(dS m^{-1})		pH	
	Initial	End	Initial	End
RW	0.51ab	0.22a	5.84a	6.30ab
RW_{RH}	0.71a	0.18a	5.70a	6.02b
RW_{P+V}	0.60a	0.20a	5.93a	6.87a
AP	0.44b	0.27a	6.43a	6.58a
AP_{RH}	0.72a	0.25a	6.28a	6.48a
AP_{P+V}	0.68a	0.27a	6.38a	6.77a
CP_{P+V}	0.76a	0.26a	6.20a	6.49a

Different lower case letter (s) indicate statistically differences ($p \leq 0.05$) between treatments

Table 4: Germination percentage (%) for *Verbena x hybrida* seeds sowing in different plug media. Values are de mean of five replicates of 20 plants each

	Germination percentage (%)	
	Day 5°	Day 10°
RW	70.8b	75.9ab
RW_{RH}	40.2c	41.1c
RW_{P+V}	78.0ab	77.2ab
AP	75.5ab	74.2b
AP_{RH}	82.2a	80.6a
AP_{P+V}	81.9ab	84.2a
CP_{P+V}	78.8ab	73.1b

Different lower case letter (s) indicate statistically differences ($p \leq 0.01$) between treatments

Table 5: *Verbena x hybrida* plant height (cm $plant^{-1}$) for different growth stages of plug production. Values are de mean of five replicates of 20 plants each

	Plant height (cm $plant^{-1}$)		
	Stage 2	Stage 3	Stage 4
RW	1.82b	3.04a	7.76a
RW_{RH}	1.38c	3.16a	5.58cd
RW_{P+V}	1.96b	3.26a	8.32a
AP	2.42a	3.62a	5.30d
AP_{RH}	2.04b	3.40a	7.34ab
AP_{P+V}	2.10ab	3.14a	4.66d
CP_{P+V}	2.14ab	3.64a	6.56bc

Different lower case letter (s) indicate statistically differences ($p \leq 0.05$) between treatments for each growth stage

Table 6: *Verbena x hybrida* leaf area (cm^2 $plant^{-1}$) for different growth stages of plug production. Values are de mean of five replicates of 20 plants each

	Leaf area (cm^2 $plant^{-1}$)		
	Stage 2	Stage 3	Stage 4
RW	0.124a	3.28ab	42.30a
RW_{RH}	0.084a	2.39bc	14.63b
RW_{P+V}	0.116a	4.46a	41.93a
AP	0.112a	4.21a	8.93c
AP_{RH}	0.126a	4.10a	16.74b
AP_{P+V}	0.086a	1.64c	5.68d
CP_{P+V}	0.084a	4.14a	15.42b

Different lower case letter (s) indicate statistically differences ($p \leq 0.01$) between treatments for each growth stage

The germination percentages were generally low but varied among mixes. The lowest values were found for RW_{RH} (river waste + rice hull) (Table 4). The highest germination results were found on Argentinean peat with rice hull (AP_{RH}) and with perlite-vermiculite (AP_{P+V}). Plant height

Table 7: *Verbena x hybrida* dry weight (mg $plant^{-1}$) for the last two plug production stages. Values are de mean of five replicates of 20 plants each

	Dry weight (mg $plant^{-1}$)					
	Stage 3			Stage 4		
	Shoot	Root	Total	Shoot	Root	Total
RW	10.02ab	6.62d	16.64d	189.44a	259.14ab	448.58a
RW_{RH}	7.20bc	7.02d	14.22d	61.68bc	162.96cd	224.64b
RW_{P+V}	10.92a	38.92bc	49.84bc	194.16a	331.60a	525.76a
AP	11.98a	67.08a	79.06a	41.74bc	77.20d	118.94c
AP_{RH}	9.32ab	25.80c	35.12c	73.38b	160.02cd	233.40b
AP_{P+V}	5.22c	50.06ab	55.28b	28.20c	268.84ab	297.04b
CP_{P+V}	10.36ab	24.26c	34.62bc	64.16b	190.94bc	255.10b

Different lower case letter (s) indicate statistically differences ($p \leq 0.01$) between treatments for each growth stage

Table 8: *Verbena x hybrida* shoot/root ratio for the last two plug production stages. Values are de mean of five replicates of 20 plants each

	Shoot/root Ratio	
	Stage 3	Stage 4
RW	1.66a	0.79a
RW_{RH}	1.22a	0.41b
RW_{P+V}	0.33b	0.68a
AP	0.21b	0.57a
AP_{RH}	0.38b	0.49ab
AP_{P+V}	0.10b	0.10b
CP_{P+V}	0.45b	0.56a

Table 9: Equations for estimating Leaf Area (cm^2 $plant^{-1}$) and Dry Weight (mg $plant^{-1}$) in *Verbena x hybrida* plug production

	Regression equations	R^2
Leaf area (cm^2 $plant^{-1}$)	$LA = -7205.28 + 2395.12\ pH + 292.18\ EC - 199.71\ pH^2 - 300.18\ EC^2$	0.995
Root dry weight (mg $plant^{-1}$)	$RDW = -10335.70 + 5211.16\ EC + 257.03\ T_p - 4302.16\ EC^2 - 1.82\ T_p^2$	0.981
Total dry weigth (mg $plant^{-1}$)	$TDW = 544.30 + 4463.38\ EC - 21.16\ A_p - 3392.76\ EC^2 + 24.80\ A_p$	0.975

EC: Electrical Conductivity (dS m^{-1}); A_p: air-filled porosity (%); T_p: total porosity (%)

showed changes during the propagation stages (Table 5). At the transplant stage the highest plant height were found on RW and RW_{P+V} mixes. There were no leaf area significant differences at Stage 2, little but significant differences among treatment at Stage 3 and showed great differences at Stage 4 (Table 6). Plants grown on RW and RW_{P+V} showed the highest leaf area expansion rate. The differences from the rest of the mixes was quite manifest, including that found on the Canadian peat-base media. At Stage 3 the highest total dry weight was found on AP, but at Stage 4 these plants had the lowest total dry weight (Argentinean peat alone) (Table 7). By the other hand, plants grown on river waste alone or with perlite-vermiculite showed the highest value dry weight. There were minor differences in shoot:root ratio, except for plants grown on treatment AP_{P+V} (Table 8).

Equations carried out to estimating growth parameters (Table 9) showed that pH and electrical conductivity of the media were associated with leaf area expansion. Electrical conductivity and total porosity influenced root dry weight accumulation while electrical conductivity and air-filled porosity were related to total dry weight. All equations showed very high regression coefficients.

Discussion

Growing media for plug production needs to support growth from the time of germination to the time to transplant. Seed germination is a direct result of a grower's ability to provide the proper microenvironment around the seed. Seed germination in the plug tray is very dependent on the moisture applied to it. Too much moisture may not allow reaching enough oxygen to germinating seeds, but insufficient moisture inhibits the physiological processes of germination (Karlovich *et al*., 1990). Water availability around the seed is related to physical properties of the media too. Of the mixes tested in this research it has been shown that the best results were found when the Argentinean peat-base substrate was used: AP_{RH} and AP_{P+V}(Table 6). However, when time from germination was over, these growing medium caused the small leaf area (Table 6) and small dry weight accumulation (Table 7).

The results showed on Table 2 would confirm that peat from Southern Argentinean cold wetlands is likely to break down rapidly, compared to the more decomposed peat from Canadian wetlands (Di Benedetto *et al*., 2006). The occurrences of small particles sizes close the air-filled pores at the top of the plug with a correlative increase in the degree of compaction of the media. The growth of algae populations on the top of the plug (data not shown) would decrease water distribution too and would lead to a water downward gradient. This effect is limited by the short time between sowing and transplant (35 days) but is more important when pot plant industry included Argentinean peat as a growing media (Di Benedetto *et al*., 2006) or when cell number per try are increasing (Di Benedetto *et al*., 2004b).

It has been indicated (Di Benedetto *et al.,* 2004a) that river waste was a good to mix with Canadian *Sphagnum* peat, although a lower stability for river waste was found after ten weeks on different perennials pot plants. The seedling quality at the transplant stage is related to plant biomass and photosynthetically active area. The higher total leaf area and dry weight with river waste growing base-media (Table 6 and 7) show how it optimizes post-transplant growth. In view of the need for progressive peat replacement, the first step towards the use of non peat-based substrates is already clear. Those substrates would be able to produce plants of better or equal quality than on the control substrate (peat-base media). As stated above, rice hull is used as a substitute for perlite and vermiculite. However, water frequency would be increased when rice hull was used (Table 5).

Verhagen (1997) has indicated that new growing media are often introduced in horticulture without knowledge about the specific characteristics of the material and crop demands. Besides this, most new growing media cannot be analyzed by the conventional methods of analysis used for peat-based media. Differing physical appearance and application in horticulture is demanding a new analytical approach. Present results (Table 9) are in agreement with his suggestions.

When physical and chemical properties of river waste and Argentinean peat were compared with light Canadian *Sphagnum* peat (Table 1) there were only minor differences. Both new material tested could be accepted as an Ideal Substrate according to Abad *et al*. (2001). However, plant responses differences were quite increasing during our experiments.

It has been indicated that chemical properties also play a major role because they govern the efficiency of nutrient supply (Guerin *et al*., 2001) and influence the environmental balance both during and after cultivation. However, when different growth parameters were related to physical and chemical properties correlation coefficients were extremely low (data not shown). Chong *et al*. (1994) using mushroom compost as a growing media for *Weigela* culture have also found that growth was a function of total pore space and not of chemical properties as assessed by electrical conductivity value at the start of the experiment. By the other hand, electrical conductivity and pH in the growing media are closely correlated with water salinity and alkalinity (Bunt, 1988). Present results are not in agreement with them because it was showed that there was not the same effect of chemical properties on both shoot and root growth. When total dry weight is analyzed, photosynthate accumulation would be associated with electrical conductivity and air-filled porosity while root dry is mainly affected by electrical conductivity and total porosity. On the other hand *Verbena x hybrida* leaf area would be related to pH and electrical conductivity (Table 9).

Substrates for germination are usually high in available water content. Lack of air is thus suspected of causing rooting problems, either due to oxygen deficiencies (Gislerod, 1983) or by accumulation of toxic substances, including bicarbonates and carbon dioxide (Drew, 1983; Veen, 1988). The regression equation for estimating total dry weight included air-filled porosity (Table 9) ($R^2 = 0.975$) and are in agreement with available bibliography.

For container-grown plants, stability of the physical properties of substrates is 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 (Heiskanen, 1995). It is generally believed that properties of substrates initially considered appropriate for plant growth may deteriorate upon ageing due to several processes. The air storage decreases as substrates age because of settling and segregation of particles of variable sizes (Bures *et al*., 1993a), shrinkage upon drying (Bures *et al*., 1993b), organic matter decomposition and physical breakdown of fibers (Nash and Laiche, 1981). These processes generally result in decreased pore sizes. As pore size decreases, air-filled porosity has often been observed to decrease associated with an increase in water retention. Since aeration is a critical process for plant growth, these decreases in air-filled porosity are generally of concern. Our results showed that total dry weight would be related to final air-filled porosity but, an analysis from leaf area and shoot dry weight failed to describe this differences again (Table 9).

The precise combination of most alternative substrates in final media mix and physiological response mechanism for different plants are lacking, our results let us state to that river waste and Argentinean peat there are a potentially alternative to Canadian *Sphagnum* peat substitute for *Verbena x hybrida* plug production. However, the use of these alternatives, with and without rice hull would require adjustment of crop management, including irrigation, fertilization and growth retardant chemicals.

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