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Alterations in the physical and physico-chemical properties of a substrate based on composted sawdust and perlite with polycyclic tomato crops

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Abstract

Vegetable crops grown continuously in greenhouse are vulnerable to phytosanitary problems or changes in the physical and chemical conditions of the soil such as salinization. One alternative to minimize these problems is to grow crops without soil using different substrates. A mixture of perlite and composted willow sawdust has been used successfully with tomatoes (*Lycopersicum esculentum* Mill), but the behavior of this substrate when reused is unknown. Factorial trials with tomato pot crops cv. Topacio were developed, and in each experiment, water content at 10, 50 and 100 cm, bulk density, pH, electrical conductivity and exchangeable cations were determined. From a physical perspective, reuse of the substrate did not substantially modify the total available water and aeration was higher than that considered as ideal. Reuse caused a light acidification and increased the C/N ratio with a loss of exchangeable cation capacity for Ca^{2+} and Na^{+}. This modification of the substrate did not affect the yield.

Key words: *Lycopersicum esculentum*, willow sawdust, fertirrigation, pot crop, crop substrates.

Resumen

Alteraciones en las propiedades físicas y físico-químicas de un sustrato a base de serrín compostado y perlita con cultivos policíclicos de tomate

El cultivo intensivo de hortalizas bajo invernadero puede inducir problemas fitosanitarios o de salinización del suelo, por lo que una alternativa es la realización de cultivos en sustrato. Una mezcla que permite cumplir con los criterios de aireación y retención de agua es la de serrín compostado de Salicáceas con perlita agrícola. Por otra parte, el cultivo de tomate (*Lycopersicum esculentum* Mill) en varios ciclos cortos presenta resultados productivos promisorios, aunque supone un mayor costo que el planteo tradicional, especialmente por el uso de sustratos. Para abaratar estos costos es necesario evaluar si el reuso del sustrato no altera sus propiedades físicas y físico-químicas. Con este objetivo se desarrollaron experimentos polifactoriales en macetas cultivadas con tomate cv. Topacio. En cada tratamiento se midió el contenido hídrico a tensiones de 10, 50 y 100 cm, densidad aparente, pH, conductividad eléctrica y cationes intercambiables. Desde el punto de vista físico, la reutilización del sustrato no modificó sustancialmente el agua total disponible, aunque esta disponibilidad sí presentó variaciones en profundidad. En cuanto a la aireación, fue superior a la considerada ideal, pero ello no implica problemas al cultivo siempre que no se altere el agua total disponible. Con la reutilización se produjo una ligera acidificación del sustrato, un notable incremento en la relación C/N y una pérdida gradual de la capacidad de intercambio de cationes y de bases de Ca^{2+} y de Na^{+}. Ninguna de estas modificaciones afecta al rendimiento del cultivo de tomate, siendo importante destacar que el Ca^{2+} es absorbido preferentemente por el cultivo y por ello se debe realizar un incremento en su aporte mediante fertirrigación.

Palabras clave: *Lycopersicum esculentum*, serrín de salicáceas, fertirrigación, cultivos en macetas, sustratos de cultivo.

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Introduction

Vegetable crops grown continuously in greenhouse are vulnerable to phytosanitary problems or changes in the physical and chemical conditions of the soil such as salinization (Abad *et al*., 1992; Abad y Noguera, 1998). These problems first appeared in the Santa Fe area (Argentina) in crops grown under plastic (Gariglio *et al.*, 2001). One alternative to minimize these problems is to grow crops without soil using different substrates.

In research carried out in this region about the physico-chemical properties of substrates, Gariglio *et al*. (2002) used agricultural perlite, composted willow sawdust and mixtures of both of these in different proportions. The mixture of 50% perlite and 50% sawdust (v:v) fulfilled criteria of aeration and water retention proposed by Ansorena Miner (1994). A similar mixture was also used with good results on a polycyclic tomato crop (Favaro *et al.*, 1997) and for growing of seedlings (Favaro *et al*., 2002) in small cell trays.

On the other hand, tomato crops grown in several short crop cycles per year (polycyclic) have been shown to produce promising yields (Favaro and Marano, 2001; Logendra *et al*., 2001a, 2001b; Fisher *et al.*,1990), although this is more expensive than traditional crops, especially because of the large amount of substrate required. To reduce costs, it would be useful to establish whether reuse of substrates for several crop cycles has any effect on their physical and physico-chemical properties. To replace the soil, the substrates should combine certain physical, chemical and biological characteristics that would permit optimum plant growth (Heiskanen, 1995).

The objective of this experiment was to study possible alterations in the physical and physico-chemical properties of a substrate reused for two tomato crop cycles.

Material and methods

A mixture of perlite and composted willow sawdust was prepared at a ratio of 1:1 (volume) in 10 L black polyethylene pots 0.25 m in diameter. Perlite granulometry was as follows: 74% smaller than 1 mm, 24% between 1 mm and 2 mm and only 2% between 2 mm and 4 mm. The pots were placed in two double rows, with a 0.20 m drainage channel between them, on soil covered with black polythene, occupying a total width of 1.2 m with a working path between them of 0.60 m, resulting in a final density of 13.3 plants m^{-2}.

Tomato cv. Topacio corresponding to the first cycle was sown in trays on the 15/10/1999 and transplanted on the 20/11, when the first inflorescence was distinguished. When the second cluster began to appear, the stem was clipped 1 or 2 leaves above the first one. The plants, with a single cluster, were trained by hanging them from a wire stretching above the row of plants.

A localized irrigation method was used, by installing lateral drip systems every 0.25 m. Fertirrigation was done using a Venturi system, applying a complete nutritive solution with a composition estimated according to the Papadopoulos procedure (1991), taking into account the nutrients supplied in the irrigation water. Irrigation was done three times a day, measuring in the drainage the electrical conductivity (ECd) of the pots every 3 days and only irrigating when this was higher than 3 dS m^{-1}.

Management of greenhouse climatic conditions included heating to protect from frosts and pest and disease management was that usually applied in the region.

After the harvest, the plant remains were removed and a second crop, sown on the 01/02/2000, was transplanted on the 05/03/2000 into the same pots, reusing the substrate. Cultivation practices and irrigation were the same as for the first cycle.

Statistical analysis corresponded to a type 3×2 bifactorial design. There were three levels for factor A (use of substrate): control (initial, without crop), first use (after the first cycle) and second use (after the second cycle). There were two levels for factor B (depths): 0-10 cm and 10-30 cm. Unaltered samples were extracted for each treatment with cylinders 5 cm high and 3 cm wide with three repeats, for the following determinations: factor A) substrate density, according to the cylinder method (Forsythe, 1975), drying the cylinders at 105ºC to constant weight; factor B) water contents at 10 cm, 50 cm and 100 cm by the suction table method (Bezerra de Oliveira, 1968), taking the samples from each treatment to saturation by capillary ascension and then performing the different suctions for 24 h.

With these determinations the following characteristic volumes were defined (Caldevilla and Lozano, 1993): 1) total porosity:

$$Pt = \left(1 - \frac{Ds}{Dp}\right),$$

where *Ds* is the substrate density and *Dp* the particle density; 2) percentage of solid matter (SM), determined by the difference between 100% and Pt; 3) aeration capacity (% A), from the difference between Pt and the volumetric water contents ($cm^3\ cm^{-3}$) retained at a suction of 10 cm; 4) easily available water (% EAW), as the difference between the volumetric water contents ($cm^3\ cm^{-3}$) retained at 10 cm and the water content retained at 50 cm; 5) reserve water (% RW), estimated from the difference between the volumetric water content ($cm^3\ cm^{-3}$) retained at 50 cm and the water content retained at 100 cm; 6) available with restrictions water (% ARW), expressed as the volumetric water content ($cm^3\ cm^{-3}$) retained at 100 cm.

Analysis of variance was done for Pt, A and the sum EAW + RW, that represents the total available water (TAW), since these are the most interesting variables for crop management.

Perturbated samples were obtained with a sampler at a single depth (0-30 cm). For each treatment, the next physico-chemical properties were determined: pH measured by potentiometry (proportion in weight of soil:water 1:2.5); exchangeable cations by extraction with NH_4N acetate at pH 7, cation exchange capacity (CEC) by displacement of NH_4^+ with $CaCl_2$ (Black, 1965); electrical conductivity (EC, proportion in weight of soil:water 1:5); percentages of total nitrogen (Nt) and of organic carbon (C), by the Walkley–Black method (Black, 1965).

Results and Discussion

The yields obtained were 8.5 kg m^{-2} for the first cycle and 8.35 kg m^{-2} for the second cycle without any significant differences in yield with substrate reuse.

Table 1. Mean values of the retention curve for each treatment

Treatment	Tension (cm)	Water contents ($m^3\ m^{-3}$)		
		10	50	100
Initial	(0-30)	42.25	38.05	34.98
1st use	(0-10)	57.40	35.89	32.57
	(10-30)	58.78	48.51	31.76
2nd use	(0-10)	52.15	36.08	27.46
	(10-30)	64.24	54.87	35.29

With this type of plant management, Logendra *et al.* (2001) grew five cycles on the same area. Table 1 gives the mean values of the retention curve for each treatment and depth.

Table 2 shows the mean values of the different characteristics compared with those corresponding to an ideal substrate according to De Boodt (cited in Caldevilla and Lozano, 1993).

It can be deduced that the material used as substrate in this experiment had a low SM content, around three times lower than that considered to be ideal by De Boodt (Caldevilla and Lozano, 1993). This implies a very high pore volume (Pt), with significant differences between the initial condition and the other uses and depths.

The initial substrate had a great aeration capacity and a high ARW value to the detriment of the EAW and RW. After the first use, A decreased, although these differences were only significant for the second use and the greater depth.

For analytical purposes it is convenient to group together EAW + RW, since the sum of these presents a potential of –100 cm, i.e. without problems for water absorption by the tomato crop.

Table 2. Mean values of the physical variables analyzed in the treatments and that corresponding to an ideal substrate

Variables	Initial (0-30)	1st use		2nd use		Ideal substrate
		(0-10)	(10-30)	(0-10)	(10-30)	
Pt (%)	94.16 a	94.79 b	94.62 b	94.63 b	94.32 ab	85
Ds (g cm^{-3})	0.116	0.104	0.107	0.107	0.113	—
A (%)	51.91 a	37.39 ab	35.85 ab	42.47 ab	30.09 b	25
EAW (%)	4.20	21.51	10.26	16.07	9.37	25
RW (%)	3.07	3.32	16.75	8.62	19.58	10
EAW + RW	7.27 a	24.83 ab	27.01 b	24.69 ab	28.95 b	35
ARW (%)	34.98	32.57	31.76	27.46	35.29	25
SM (%)	5.84	5.21	5.38	5.37	5.68	15

Values with the same letter do not present significant differences according to the Tukey test with $\alpha = 0.05$. Pt: total porosity. Ds: substrate density. A: aeration capacity. EAW: easily available water. RW: reserve water. ARW: available with restrictions water. SM: solid matter.

This value of TAW significantly increased after the first use, although differences were only significant at a depth of 10-30 cm, close to the optimum value for an ideal substrate. There were no significant differences between both depths and it was, therefore, concluded that after one cycle of use the total availability of water for the crop increased in the whole potential root depth. A similar occurrence was observed for the second use, with mean differences of around 65% of EAW + RW between the two depths, but when both were added together this difference was reduced to 15%. If values of EAW + RW were estimated for each depth for the first and second use, no differences were found between these, implying that the substrate used does not present any limitations to its water retention potential.

This is understandable given the high value of A in the initial substrate that after successive use is transformed into total useful water (EAW +RW), permitting the substrate to approach ideal conditions.

Causes for this sharp decrease in A are based on the strong microbiological activity of the substrate, that causes the sawdust to decompose and to break up into finer particles, permitting greater water retention. Similar results in relation to the decrease in A were obtained by Gariglio *et al*. (2002) working with this type of substrate both in composted and non-composted form. This would mean that after one or two tomato crop cycles, a substrate with sawdust would physically behave as if it had been composted.

Figure 1 shows the retention curves for the different treatments relative to that of a substrate considered to be ideal by De Boodt (Caldevilla and Lozano, 1993). From a physical perspective, reuse of the substrate did not substantially alter the total available water (EAW + RW), which varied with depth (10-30 cm). The variable A was higher than the ideal value but this does not cause any problems for the crop provided that the total available water does not alter. The volume of ARW was high for all treatments and depths implying that attack of the organic soil fraction by microorganisms reduced the proportion of A to the benefit of the sum EAW + RW, without altering ARW. The increased de-

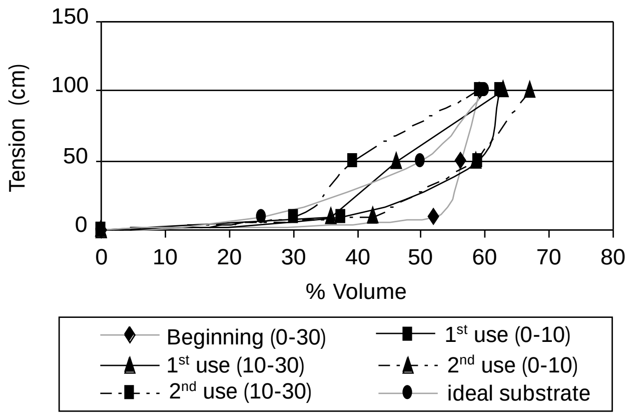

Figure 1. Substrate retention curves for different uses.

composition of the OM would probably increase the finest fraction of substrate by reducing the particle size with the consequent increase in water contents at a tension of 100 cm and an increase in ARW, as occurs with the production of willow sawdust compost (Gariglio *et al.*, 2002).

Table 3 shows the mean values of pH, EC, OM, Nt and C/Nt ratio for each treatment. The increase in C/N ratio as a function of greater substrate reuse occurred because of an important decline in Nt and reflects immobilization of nutrients (Caldevilla and Lozano, 1993), meaning that these would have to be supplied by fertirrigation to satisfy the crops requirements.

The mean values of CEC, exchange bases, sum of bases (S) and exchangeable sodium percentage (ESP) corresponding to the different treatments are presented in Table 4. The high values of CEC are caused by the organic component of the substrate, since perlite can be considered as almost inert. The differences between values of S and CEC are based on the extraction method that used ammonium acetate at pH 7 (Marano *et al.*, 2000). However, it is noteworthy that the substrate did not present exchangeable acidity in spite of the pH values being slightly lower with each use.

In the initial condition, the bases Ca^{2+}+ Mg^{2+} predominated with Ca/Mg ratios above 1, a limit at which the Mg^{2+} content is not considered to be damaging (Ayers and Westcot, 1987). Moreover, the initial Na^{+} content was high (ESP>10%), although this did not

Table 3. Electrical conductivity (EC), organic matter (OM), total nitrogen (Nt) and C/N ratio. Mean values of treatments

Treatment	pH	EC (dS m^{-1})	OM (%)	Nt (%)	C/N
Initial	7.1	0.84	27.5	0.73	19
1st use	6.8	0.48	22.5	0.40	28
2nd use	6.3	0.43	29.0	0.25	59

Table 4. Exchange cations, cation exchange capacity (CEC), sum of bases (S) and exchangeable sodium percentage (ESP) of treatments

Treatment	Ca^{2+} ($cmol_c\ kg^{-1}$)	Mg^{2+} ($cmol_c\ kg^{-1}$)	K^+ ($cmol_c\ kg^{-1}$)	Na^+ ($cmol_c\ kg^{-1}$)	CEC ($cmol_c\ kg^{-1}$)	S ($cmol_c\ kg^{-1}$)	ESP (%)
Initial	25.3	8.1	1.8	2.9	28.9	39.1	10.8
1st use	20.9	8.8	0.6	2.8	32.0	33.1	9.1
2nd use	16.0	9.1	1.6	2.0	27.1	28.7	7.5

imply a reduction in crop yield since the K^+ composition remained normal.

After the first use, all the bases decreased except for Mg^{2+}, probably due to extraction by the crop and leaching caused by the lixiviation ratio (LR) used in the irrigation. In the second use, Ca^{2+} extraction and leaching of Na^+ increased and the Ca^{2+}/Mg^{2+} ratio could approach the critical value of 1 if the substrate is reused again. In the second use, K^+ was increased probably due to the input from the fertirrigation.

Reuse produces a slight acidification of the soil substrate, a pronounced increase in the C/N ratio and a gradual loss of CEC and of Ca^{2+} and Na^+ bases, although none of these alterations in any way harmed the tomato crop. It is important to point out that the Ca^{2+} ion is preferentially absorbed by the crop and because of this its intake should be increased by fertirrigation to maintain a Ca^{2+}/Mg^{2+} ratio higher than 1.

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