

COMPOSTED ORGANIC RESIDUES AS A SUBSTRATE COMPONENT FOR TOMATO TRANSPLANT PRODUCTION

M. Reis	F.X. Martinez, M. Soliva	A.A. Monteiro
Universidade do Algarve	Escola Superior	Instituto Superior
UCTA	d'Agricultura de Barcelona	de Agronomia
Campus de Gambelas	08036 Barcelona	1300 Lisboa
8000 Faro	Espanha	Portugal
Portugal		

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Abstract

Pine bark and grape marc composts were tested in the production of tomato seedlings as substrate components after composting in 1.2 m³ boxes. The composting process of pine bark took 20 weeks with a low temperature increase. Grape marc composting process took 16 weeks, reaching a higher temperature. Composts were used as single substrate components and in mixtures with a *sphagnum* peat, in the proportions of 25, 50 and 75% (v/v) of compost. Tomato seeds were seeded in modular trays of 35 cm³ and irrigated by "ebb and flood" irrigation system. The growth of tomato plants in the mixtures was similar or better than in a standard peat substrate, mainly in the first year of trials. Pine bark performed generally better than grape marc. Plant growth was significantly correlated with the physical properties of the substrates mainly in grape marc mixtures and in the trials under higher levels of radiation. A higher incorporation of compost determines a lower water retention capacity and a poor performance of the mix. Good tomato seedlings growth was possible using mixtures with an incorporation of composts reaching 100% of pine bark and 50% of grape marc.

1. Introduction

Peat mixes are the most common substrates in pot plant production (Raviv *et al.*, 1986; Abad *et al.*, 1993) but the use of composted organic residues as substrate components is increasing. Composts of pine bark are well known, mainly in pot plant production (Hoitink, 1980; Handreck and Black, 1991). Grape marc compost is less used (Handreck and Black, 1991; Abad *et al.*, 1993). Composts for substrate mixtures must be of high quality (Zucconi and Bertoldi, 1987; Inbar *et al.*, 1993), which can only be achieved when the organic residues are adequately composted. There is a need for characterizing the composting process and the final products, in order to predict the potential value of the composts as substrate components.

The objective of this research was to characterize the composting process of pine bark and grape marc, to test their use as components of peat mixtures for tomato transplant production, and to relate the physical characteristics of the composted materials with their performance as substrate.

2. Materials, Methods, Experiments

2.1 Composting

Pine bark (*Pinus pinea* L. and *P. pinaster* Ait.) and grape marc (of red wine, not distilled) were composted in 1.2 m³ insulated polythene boxes. Pine bark (PB) was milled in a hammer mill and received a supplement of urea at 3.3 kg m⁻³. Grape marc (GM) was not milled and received no urea supplement due to its original low C/N ratio. The composting of PB was activated by adding sewage sludge. After the addition of sewage sludge (20% v/v) only a small increase in temperature was observed, and so, a second application of sewage sludge of different age was made (7.5% v/v). The composting process was controlled by monitoring temperature daily and humidity, pH and EC weekly. Chemical and physical parameters were determined monthly in fresh or dried samples as follows: pH, with a potentiometer (Crison 2001, Crison Instruments) in a 1:2 water extract of a 100 cm³ volume sample measured under a pressure of 10 g cm⁻² (Martinez e Casasayas, 1988); electrical conductivity (EC), with a conductivimeter (Crison 522, Crison Instruments) in the pH extract (Martinez e Casasayas, 1988); organic matter (OM) by calcination at 560 °C for 3 h; organic nitrogen (Norg) by Kjeldahl method in Soliva *et al.* (1990); decomposition degree (DD) *cit. in* Ramos (1987); ammoniacal nitrogen (N-NH₄) by distillation with NaOH; non-hidrolizable nitrogen (Nnh) by Kjeldahl method, on the remaining residue from decomposition degree determination; oxidable carbon (Cox) by a modification of Suerlandt in Soliva *et al.* (1990); cation exchange capacity (CEC) by the method of Harada and Inoko (1979); extractable nutrients were determined by the CaCl₂/DTPA method (Alt and Peters, 1993); germination index (GI) by a modification of Zucchini (1985), consisting on the use of an extract obtained from a 20 g (dried weight) of fresh sample with no previous adjustment of humidity and 250 mL of distilled water, agitating for two hours, remaining for 2 h at 40 °C, filtering by double paper filter and using the extract with no dilution. Total pore space (TPS), air-water relations (air capacity (AC), easily available water (EAW), water buffering capacity (WBC) and difficult available water (DAW)), bulk density and real density were determined according to De Boodt (1974).

2.2 Substrate testing

PB and GM were composted in spring. The composts were kept at room temperature until the 1st growth trial, in the following winter and then kept at 4 °C to be used in the following trials. Materials were physically and chemically characterised before, during and after composting (Table 1).

Composts were sieved (5 mm sieve) and used as single substrate components and in mixtures with a *sphagnum* peat (Floratorf, Torfstreuverband GMBH, Germany), with pH adjusted to 5.8, with 25, 50 and 75 % (v/v) of compost, measured under a pressure of 10 g cm⁻². A commercial peat mixture was used as control (Triohum Traysubstrat, Klassman - Deilmann, Germany). The control and the mixtures received 1.3 g cm⁻³ of PG Mix fertilizer (14 N-18 P₂O₅-18K₂O-0,7 MgO plus micro elements), and were tested in the production of tomato seedlings in polystyrene cellular trays (128 x 34 cm⁻³), in four experiments conducted in Dec.-Feb. and Feb.-Mar. of two consecutive years (Table 2). The 9 treatments, consisting of the compost mixtures and the peat control were arranged in a completely randomized block design, with four replicates and 12 cellular trays in total. Seeds of tomato were planted in each cell and the trays placed on a heated bench inside a PE greenhouse. The seedlings were watered by a “ebb and flow system” with tap water before cotyledon expansion and thereafter with a nutrient solution containing (mmol L⁻¹): NH₄⁺ 0.3, K⁺ 2,6, Na⁺ 0.8, Ca⁺⁺ 1.0, Mg⁺⁺ 0.7, NO₃⁻ 4.2, Cl⁻ 0.5, SO₄⁻ 0.9, P 0.4; (μmol L⁻¹): Fe 4.0, Mn 1.6, Zn 3.3, B 8.0, Cu <0.5). The frequency of irrigation varied between 1 and 2 days and was determined by the visual observation of the water status of the mixtures.

At the end of the experiment a sample of 6 plants per treatment and replication was used to determine plant height (from substrate level to plant apex); stem diameter (above substrate level) and fresh weight (aerial part only). Data were subjected to ANOVA and the means were separated by Duncan's test (SAS software). The correlation between physical and chemical properties of the mixtures and plant growth parameters was determined (EXCEL software).

3. Results

3.1 Composting

The composting process of GM took about 16 weeks and reached a maximum temperature of 77.3 °C. A small change in pH was detected as well as in OM and DD. There was a slight increase of EC and Cox. C/N relation, initially low, had no significant change. GI, initially to low, increased to normal level (Table 1). The physical changes were very small (Table 1). GM compost had an high air capacity (49%) but a low easily available water (3%).

In PB composting the initial increase in temperature was very low (44.3°C) and temperature stabilisation occurred just after 4 weeks (Fig. 1). The addition of sewage sludge (20% v/v) gave an insignificant. temperature rise. The second addition of sewage sludge (7.5% v/v), resulted in a higher temperature increase (35 °C) stabilising 5 weeks later (about 20 weeks after the composting process start). The volume of compost decreased 11% during composting (Table 1). The decrease in organic matter content was influenced mainly by the addition of the sewage sludge (Table 1). No reduction was observed in the decomposition degree. Oxidable carbon decreased as

well as C/N relation. An increase in Norg, Nnh and CEC was observed. GI was already in normal level since the beginning of the process. A small change of the physical properties was observed (Table 2). PB-sewage sludge compost had a good air capacity (30%) but a low easily available water (12%).

Although PB has a natural decomposition resistance, the chemical determinations suggest that the PB used to make the compost was already aged, which may explain the reduced temperature increase during composting. GM showed a high decomposition resistance.

3.1 Substrate testing

Good plant growth was obtained with most of the mixtures (Table 3 and 4). In the first year, all the mixes performed as well as the control in the first trial, but in the second trial the plants on GM mixes containing 50% to 100% compost were shorter. In the second year, the plants in compost mixtures showed a smaller growth than the control, in the first trial, but a better performance was observed in the second trial, mainly with PB mixtures. Plant growth was correlated with some physical characteristics of the substrates, mainly total pore space, and particularly in GM mixes (Table 5). A higher number of significant correlations was found in the second trial of each year, during which there was a higher water demand, due to higher temperature and radiation.

4. Discussion

In GM composting, only occurred a slight modification of the original material, but the decrease in N-NH₄ and the increase in N-NO₃ and CEC indicate some stabilisation process. The low variation of the physical variables is related to the nature of GM, which is highly resistant to degradation due to the presence of many seeds. The small temperature increase in PB-sewage sludge and the evolution of the variables DD and GI indicate a high stability of PB, probably due to a relatively high period of conservation in the saw-mill.

Increasing the percentage of compost in the mixtures reduced plant growth mainly in the second trial of each year (Table 3), owing to the higher water demand during this period that could not be met by the lower water availability of the mixtures with an higher percentage of compost. The effect of substrate in the mixture is more accentuated in GM mixtures which have a lower water availability.

The results of plant growth trials showed the big influence of the physical characteristics of substrates on plant growth and that a good plant growth can be obtained by using PB and GM composts for the production of tomato seedlings. PB can be used alone but GM needs the addition of a minimum of 50% peat.

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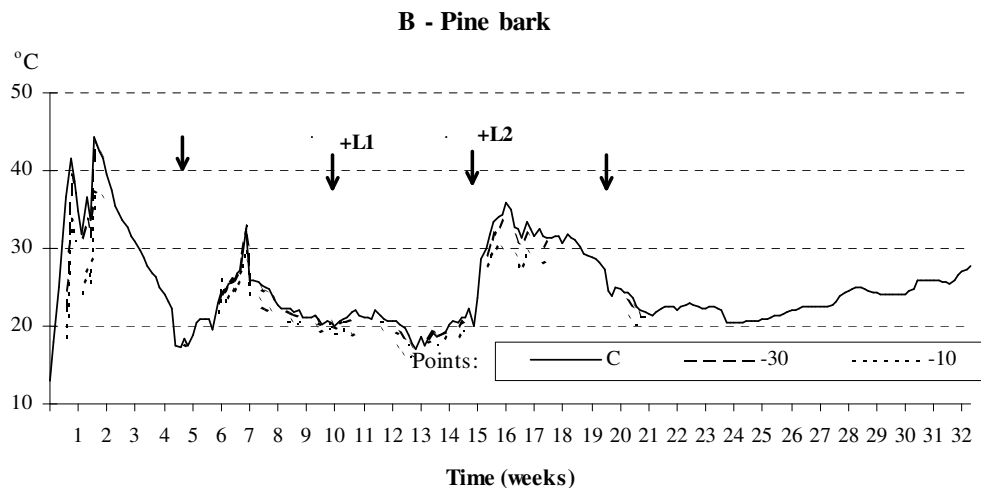
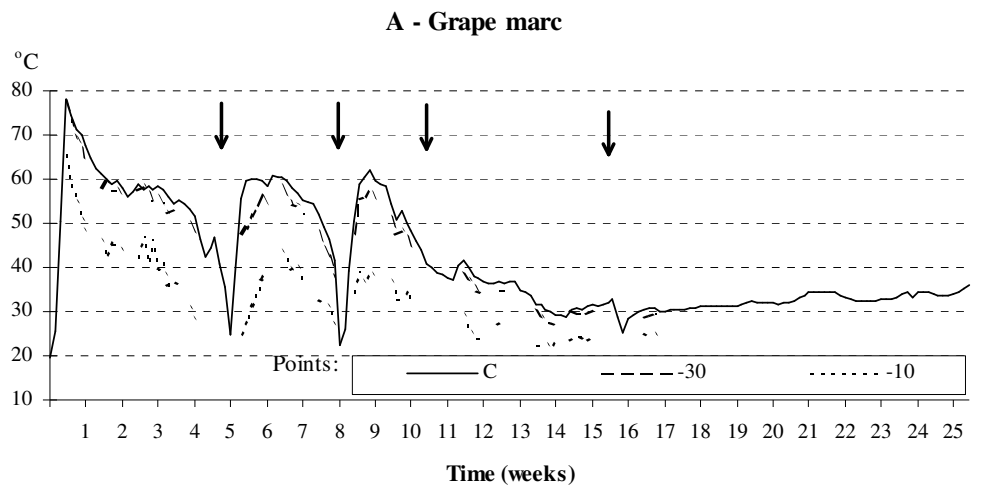


Figure 1 - Temperature variation during the composting of grape marc (A) and pine bark (B) in the center (C), at 30 cm from the surface (-30) and at 10 cm from the surface of the material (-10). Arrows (↓) indicate the turning of the material and the addition of water; +L1 and +L2, indicate the addition of sewage sludge.

Table 1 -Chemical and physical changes during grape marc and pine bark composting

Grape marc		Week						
Variables ^v		0 ^f	1 ⁱ	4	8	12	16	20
DM (%)		58.3	-	58.0	59.9	45.2	42.4	43.3
pH		7.27	-	6.97	7.18	6.48	6.82	7.20
EC (dS m ⁻¹)		0.325	-	0.435	0.306	0.273	0.483	0.732
OM (%)		88.8	-	91.2	91.5	90.0	89.5	88.8
Norg ¹ (%)		2.28	-	2.05	2.26	2.10	2.21	2.58
DD (%)		65.5	-	-	69.4	-	69.3	67.1
N-NH ₄ (%)		0.253	-	0.229	0.232	0.126	0.172	0.125
Nnh (%)		1.17	-	-	0.56	-	0.91	1.84
Cox (%)		40.9	-	39.9	45.9	46.5	42.4	42.9
C/N		18	-	19	20	22	19	17
CEC (meq/100g DM)		60.4	-	-	-	-	91.3	87.6
GI		10	-	-	-	-	151	
rd (g cm ⁻³)		1.528	-	1.510	1.508	1.518	1.522	1.527
bd (g cm ⁻³)		0.242	-	0.250	0.235	0.236	0.237	0.231
AC (% v/v)		49.0	-	50.8	53.3	52.2	46.6	49.3
EAW (% v/v)		4.8	-	2.5	2.4	3.4	4.8	3.1
WBC (% v/v)		0.7	-	1.4	0.4	1.7	1.3	0.9
DAW (% v/v)		29.7	-	28.7	28.3	27.2	31.7	31.7
TPS (% v/v)		84.2	-	83.4	84.4	84.5	84.4	84.9

Pine bark		Week								
Variables ^v		0 ^f	1 ⁱ	4	8	12	16	20	24	28
DM (%)		56.5	59.3	50.8	43.2	50.7	49.5	52.1	50.2	51.9
pH		6.88	7.08	7.90	5.35	5.28	5.94	5.62	5.79	5.70
EC (dS m ⁻¹)		0.088	0.120	0.097	0.534	0.911	0.898	1.082	1.481	2.870
OM (%)		70.5	70.4	77.2	79.0	53.9	53.7	49.0	50.2	50.7
Norg (%)		0.20	0.22	0.88	0.55	0.82	0.79	0.76	0.80	0.98
DD (%)		62.8	61.4	64.6	59.3	60.3	62.6	61.4	62.5	62.5
N-NH ₄ (%)		0.103	0.046	0.225	0.083	0.084	0.093	0.087	0.102	0.066
Nnh (%)		-	0.28	0.50	0.38	0.60	0.39	0.47	0.47	0.47
Cox (%)		33.9	35.6	41.8	39.7	29.7	28.4	27.2	25.9	27.4
C/N		170	162	48	72	36	36	36	32	28
CEC (meq/100g DM)		-	44.2	-	-	47.7	-	-	47.0	49.1
GI			94						209	
rd (g cm ⁻³)		1.628	1.630	1.530	1.505	1.868	1.871	1.939	1.923	1.915
bd (g cm ⁻³)		0.280	-	-	-	0.360	-	-	0.370	0.370
AC (% v/v)		35.1	-	-	-	33.3	30.8	-	28.8	30.0
EAW (% v/v)		10.1	-	-	-	12.2	12.6	-	12.3	12.4
WBC (% v/v)		1.4	-	-	-	2.2	2.9	-	0.9	3.2
DAW (% v/v)		36.3	-	-	-	33.0	34.5	-	38.8	35.1
TPS (% v/v)		82.8	-	-	-	80.7	80.8	81.4	80.8	80.7

^ffresh material; ⁱinitial day of composting

^v DM, dry matter content; EC, electrical conductivity; OM, organic matter; Norg, organic nitrogen; DD, decomposition degree; N-NH₄, amoniacal nitrogen; Nnh, non hidrolizable nitrogen; Cox, oxidable carbon; C/N, oxidable carbon/ organic nitrogen relation; CEC, cation exchange capacity; GI, germination index; rd, real density; bd, bulk density; AC, air capacity; EAW, easily available water; WBC, water buffering capacity; difficult available water; total pore space.

Table 2 - Nursery growing conditions

	1993		1994	
	1 st trial	2 nd trial	1 st trial	2 nd trial
Start	13 Dec	15 Feb	14 Dec	15 Apr
End	07 Feb	28 Mar	15 Mar	17 May
Duration (days)	56	42	63	32
Mean air temperature (°C)	14.7	19.6	16.9	22.9
Mean of min. air temperature (°C)	3.3	10.6	6.8	12.2
Mean of max. air temperature (°C)	26.4	28.5	27.1	33.6
Cultivar	“Edison”	“Radja”	“Radja”	“Radja”
Bench minimum temperature (°C) (initial → final)	-	25 → 8	25→8	25

Table 3 - Plant height (H), stem diameter (D) and plant fresh weight of canopy (FW) of tomato plants grown in compost mixes

Substrate	Compost %	1993 1 st trial			1993 2 nd trial		
		H (cm)	D (mm)	FW (g)	H (cm)	D (mm)	FW (g)
Control		13.5bc	3.1d	2.3bcd	18.1cd	4.3ab	6.2bc
Grape marc compost mixtures	25	14.0ab	3.5ab	2.6ab	18.3bcd	4.3a	6.3bc
	50	14.5a	3.6a	2.6a	17.6d	4.1c	4.8d
	75	13.9ab	3.6a	2.5ab	15.4e	3.9d	4.0e
	100	12.8c	3.5a	2.0d	12.8f	3.7e	2.7f
Pine bark compost mixtures	25	12.9c	3.1d	2.1cd	19.1bc	4.4a	7.2a
	50	13.1c	3.4bc	2.3bcd	20.0a	4.3ab	6.8ab
	75	13.3bc	3.3bc	2.4abc	19.1b	4.3ab	6.7ab
	100	13.2bc	3.2cd	2.1cd	18.6bc	4.1bc	6.0c
Substrate	Compost %	1994 1 st trial			1994 2 nd trial		
		H (cm)	D (mm)	FW (g)	H (cm)	D (mm)	FW (g)
Testimony		11.9a	3.0a	1.9a	14.1a	3.2abc	2.2a
Grape marc compost mixtures	25	9.6cd	2.7bcd	1.2cd	13.4a	3.3ab	2.4a
	50	10.0bcd	2.7cd	1.3bc	12.6a	3.4a	2.2a
	75	9.1d	2.7cd	1.2cd	9.2b	2.9cd	1.1b
	100	7.5e	2.7cd	1.0d	4.3c	1.9e	0.2c
Pine bark compost mixtures	25	9.1d	2.7cd	1.1cd	12.7a	3.3abc	2.4a
	50	10.3bc	2.8bc	1.4bc	14.6a	3.2abc	2.2a
	75	10.8b	2.9ab	1.5b	12.8a	3.0bcd	1.8ab
	100	9.3cd	2.6d	1.1cd	11.4ab	2.7d	1.2b

Table 4 - Linear (L) and quadratic (Q) effect of the compost rate in the mixture on plant growth (plant height (H), stem diameter (D) and plant fresh weight of canopy (FW))

Substrate	1993 1 st trial						1993 2 nd trial					
	H (cm)		D (mm)		FW (g)		H (cm)		D (mm)		FW (g)	
	L	Q	L	Q	L	Q	L	Q	L	Q	L	Q
Mixes with:												
Grape marc	***	***	ns	ns	***	***	***	***	***	***	***	***
Pine bark	ns	ns	ns	*	ns	ns	ns	*	***	**	**	**

Substrate	1994 1 st trial						1994 2 nd trial					
	H (cm)		D (mm)		FW (g)		H (cm)		D (mm)		FW (g)	
	L	Q	L	Q	L	Q	L	Q	L	Q	L	Q
Mixes with:												
Grape marc	ns	*	ns	ns	**	***	***	***	***	***	***	***
Pine bark	ns	**	ns	**	ns	***	ns	*	*	**	***	***

^a Effect of the compost rate in the mixture on plant growth: ns, not significant; * significant for $p \leq 0.05$; ** significant for $p \leq 0.01$; *** significant for $p \leq 0.001$.

Table 5 - Correlation coefficients^a of substrates properties and growth variables of the tomato plants growing on compost mixtures

Substrate properties	1993					
	1 st trial			2 nd trial		
	Growth variables ^b			Growth variables ^b		
Grape marc compost mixes	H	D	FW	H	D	FW
Bulk density	ns	ns	ns	-0.963*	-0.999**	-0.991**
Total pore space	ns	ns	ns	0.961*	1.000**	0.991**
Air capacity	ns	ns	ns	-0.953*	-0.998**	-0.998**
Nutrients	ns	ns	ns	-0.974*	-0.996**	-0.995**
Pine bark compost mixes	H	D	FW	H	D	FW
Bulk density	ns	ns	ns	ns	ns	-0.972*
Total pore space	ns	ns	ns	ns	ns	0.973*
Air capacity	ns	ns	ns	ns	ns	ns
Nutrients	ns	ns	ns	ns	ns	-0.958*
	1994					
Substrate properties	1 st trial			2 nd trial		
	Growth variables ^b			Growth variables ^b		
	H	D	FW	H	D	FW
Grape marc compost mixes	H	D	FW	H	D	FW
Bulk density	ns	-0.962*	ns	ns	ns	-0.961*
Total pore space	ns	0.964*	ns	ns	ns	0.960*
Air capacity	ns	-0.955*	ns	ns	ns	ns
Nutrients	ns	ns	ns	-0.958*	ns	-0.969*
Pine bark compost mixes	H	D	FW	H	D	FW
Bulk density	ns	ns	ns	-0.955*	ns	-0.981*
Total pore space	ns	ns	ns	0.953*	ns	0.980*
Air capacity	ns	ns	ns	ns	ns	ns
Nutrients	ns	ns	ns	ns	ns	-0.968*

^a Symbols: *, ** and ***, indicate a correlation coefficient significant for $p \leq 0.05$, $p \leq 0.01$ and $p \leq 0.001$; ns, not significant.

^b Growth variables: H, height; D, stem diameter and FW, fresh weight of canopy.