Grape Marc and Pine Bark Composts in Soilless Culture[1]

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Abstract

Grape marc and pine bark were composted in windrows for a period of three months, supplied with 1kg of nitrogen (urea) m^{-3}. Grape marc compost (GMC) and pine bark compost (PBC) had, respectively, 84.3 and 85.0% v/v total pore space, 10.3 and 1.2 % v/v easily available water, 59% and 32.0% v/v air capacity, 53.0 and 25.9 % v/v total water content. Rockwool (Grodan®) has higher total pore space (96.7% v/v) and total water content (81.8% v/v) but lower air capacity (14.9% v/v). Rockwool, GMC and PBC were compared as plant substrates for growing a greenhouse tomato crop. Plants of tomato 'Sinatra' (Sluis & Groot, Holland) were grown on 15 L rockwool slabs and on 30 L bags of compost, in a heated plastic greenhouse, from December to June. A nutrient solution with the same chemical composition was used for the three substrates, varying the composition according to plant development. The irrigation period was pre-set and the irrigation frequency was controlled by solar radiation. Fruits were collected twice a week, from March to June, weighted and selected. There were no significant differences in yield and fruit quality between substrates. Commercial yield on GMC was 16.6 kg m^{-2}, on PBC 15.5 kg m^{-2} and on RW 16.2 kg m^{-2}. Temperature in composts showed a higher resistance to daily variation. We observed a good root development after the crop, specially in GMC. Positive changes in the physical properties of composts occurred during the growing period, particularly the increase in water content of GMC and in aeration capacity of PBC, indicating a potential re-using the composts, which was lately confirmed by growing a second and third tomato crop, on GMC (open and closed systems[1]) and on PBC (open system[2]).

INTRODUCTION

In the last decades an increased interest on soilless culture was observed. Different materials, both organic and inorganic, can be used as plant substrates depending on the local technical and economical conditions and on the objectives of the culture (Bunt, 1976; Benoit, 1990). The use of composts in the preparation of the substrates has generated a great interest because of the physical, chemical and biological properties of composts (Hoitink, and Poole, 1980; Pudeldski, 1987; Abad et al., 1993; Hoitink et al., 1997). In addition, composting organic residues offers the possibility of recycling materials, obtaining a valuable product, which can locally replace imported substrates (Reis, 1997).

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The objective of this work was to test grape marc and pine bark composts as alternatives to rockwool in greenhouse tomato production, in an open cultivation system.

MATERIALS AND METHODS

Substrates

Grape marc (*Vitis vinefera* L.) was obtained from a local winery (Adega Cooperativa de Lagoa, Algarve) and pine bark (*Pinus pinea* L.) was obtained from a sawmill (Alcacer do Sal, Alentejo). Both materials were composted for three months in a windrow, after the addition of nitrogen (urea at 2 kg m^{-3}). Grape marc compost (GMC) and pine bark compost (PBC) were used in 30 L polyethylene bags (1 x ∅ 0.2 m). Physical and chemical properties of GMC were determined (Table 2). Total pore space (TPS), air capacity (AC), easily available water (EAW), water buffering capacity (WBC), difficult available water (DAW) and the total water (TW) were determined according to De Boodt *et al*. (1974) method. Particle density (pd) was determined from the organic matter and ashes content (Martinez, 1992). Bulk density was determined following an adaptation of Boodt *et al*. (1974) method, which consisted in the direct determination of the water content of the material by weighing the cylinder with the fresh material after drying at 105 ºC. Cation exchange capacity (CEC) was determined according to Harada and Inoko's (1979) method. Volatile solids (VS) were determined by calcination of milled dry sample at 560ºC for 3 h (Ramos *et al*., 1987).

Rockwool (RW) (Grodan®, Grodan B.V., Holland) was used in 15 L slabs (1 x 0.1 x 0.015 m, wrapped, two years)

Cultivation system

A cultivation system was installed in a polyethylene greenhouse (32.5 x 36 m) with roof and side natural ventilation. Heating was provided by hot water in polyethylene corrugated pipes (15 Wh m^{-1}).

The containers with the substrates (slabs and bags) were placed on polystyrene slabs, inside gutters of polyethylene film. Two heating pipes were placed inside the gutters, one on each side of the substrate containers and two more pipes 1m above ground. The heating system worked from 22h00 to 10h00, controlled by a thermostat adjusted to 16-18 ºC, from December until April.

Water from a well was used for irrigation (Table 1). Two fertiliser tanks were used for A and B nutrient solutions, plus a third tank for the acid solution (HNO_3). Different nutrient solutions were used along the cropping cycle (Table 1). Nutrient solutions were the indicated for rockwool. A computerized system was used to prepare and control the nutrient solution (AMI 1000, DGT-Volmatic, Denmark). Irrigation period was pre-set and irrigation frequency was controlled by accumulation of solar radiation. Three self-compensating and anti leak emitters (3 L h^{-1}, Plastro, Israel) were used per container. The automatic control of irrigation was based on the volume of drainage in RW, which was kept between 20 and 30% by varying the frequency (adjusting the value of radiation accumulation that would start a new irrigation), and/ or the irrigation period. Irrigation was daily monitored by measuring the volume, the EC (LF 91, WTW, USA) and the pH (DGT Volmatic, Denmark) of the irrigation and the drainage solutions. The nutrient content of the solutions was determined once a month.

In both trials, six tomato plants (*Lycopersicum esculentum* Mill.) 'Sinatra' (Sluis & Groot, Holland) were cultivated in each substrate container (2.2 plants m^{-2}).

Tomato growing trials

Tomato production was compared in RW, GMC and PBC in a open system.

Tomato was grown from 97.12.12 to 98.06.27. Fruits were collected twice a week and graded into classes: Extra (E), I, II and Not commercial (NC) (CEE, 1990). Fruit in classes Extra, I and II was designated as commercial production (C). In April, May and June of each year, a random sample of 1 kg of fruit per treatment and replicate was taken to determine pH (potentiometer, WTW FF 91), dry soluble residue (digital refractometer, ATAGO PR1, EC Journal: L55/43) total acidity (titration, expressed in g of citric acid per 100 cm^3, NP 1421/77); maturation index (calculated by the relation ºBrix/ total acidity), nitrates (photometry, LASA), ashes (gravimetry after calcination at 550ºC), dry matter content (gravimetry after drying at 70 ºC).

The experiments were laid out using a complete randomised block design: 3 substrates x 3 replicates. Fruit yield and number were determined in 12 plants per replicate. The data were analysed with Analysis of variance (ANOVA) and Duncan's multiple range test using SAS® (SAS Institute Inc., Cary, U.S.A.)

RESULTS AND DISCUSSION

Substrate properties

Grape marc and pine bark composts were relatively coarse materials, with a high total pore space, respectively 84.3 and 85.0% v/v. (Table 2). However, GMC had a much higher air capacity (respectively 59.0% and 32.0 % v/v) and retained less water than PBC (respectively 25.9% and 53.0 % v/v).

Rockwool has a high total pore space (96.7 %) but a much lower air capacity (14.9 % v/v) than GMC. Most of the water of RW is retained under a tension between 10 and 100 cm of a water column (77.8% v/v of 81.8% v/v).

During the growing period, there were almost no changes in total pore space, but positive changes occurred in the physical properties of composts, particularly the increase in water content of GMC and in aeration capacity of PBC. This result is according to the observation of culture bags with these composts, which were used for several years (one culture per year) without significant visual physical changes.

Mean temperature in composts was usually lower than in rockwool during the coldest period of the trial (January to March) (Table 3). However, during the warmer months (April to June) the mean temperature in composts was usually higher than in rockwool. During the coldest day of the trial, in the coldest period, during the day (when the substrate heating system was off), the temperature in the composts was lower than in rockwol (Figure 1). In the example, near midday, temperature in the composts, was three to four degrees lower than temperature in rockwol. By the end of the afternoon (before the re-start of the heating system) the temperature of the three substrates went closer, because temperature in rockwool decreased faster. During the night (with the heating system on) temperature in rockwol increased more rapidly than in composts, keeping about two degrees above temperature in composts. Early morning, after the heating system was turned off, temperature in rockwool increased more rapidly than in composts. This indicates an higher termic inertia of composts. When the substrate is heated, the lower termic inertia of rockwool can be more favourable because it will be cheaper to keep it warm during the night. On the other hand, during the day, higher temperature can be reached in rockwool, which could be favourable or not, according to the conditions.

When there was no substrate heating, the difference between the temperature of the three substrates was lower (Figure 2). For example, during the coldest day of the trial, mean temperature of substrates was 13.2, 13.3 and 12.7ºC respectively in RW, GMC and

PBC. After sunset, temperature in rockwool decreased below temperature of composts, up to 1.2ºC relatively to grape marc and 0.7 relatively to pine bark. By the contrary, after sunrise rockwool temperature increased relatively to grape marc (up to 2.1 ºC) and to pine bark (up to 1.4ºC). The higher termic inertia of composts, due to their differences in moisture content, physical properties and larger container volume can be taken into account in order to play a positive role on plant development related to plant root environment.

After the crop the root system was visually examined. A good root development was observed, specially in grape marc compost.

Tomato yield

The yield of tomato grown on composts was not significantly different from the yield on rockwool slabs (Table 4).

Compost bags used in this trial were used in two consecutive years (Reis et al. 2000), with one tomato crop per year, in open and closed systems without a clear decrease of production potential (Table 5).

Tomato quality

No differences on the quality parameters were observed between fruits from plants on the three substrates, except in last observation (at the end of the cropping period), a lower total acidity on fruits from GMC (Table 6).

CONCLUSIONS

Greenhouse tomato grown on culture bags of grape marc and pine bark composts showed no differences on yield and fruit quality when compared to rockwool slabs.

Composts physical properties, namely air capacity and water retention, showed a positive evolution during the growing period suggesting their potential for use on several crops. Culture bags with the composts were used in two consecutive years with one tomato culture per year, with no clear decrease in their potential as substrates.

Composts showed a higher resistance to temperature variation, which influences their performance as substrates with and without substrate heating. Temperature stability can be useful to prevent large temperature fluctuations in the plant root during periods of high daily air temperature amplitude, often observed in Spring season in Mediterranean areas.

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Tables

Table 1 – Ion content of the irrigation water (well) and the of standard nutrient solutions

	NO_3^- meq L^{-1}	NH_4^+ meq L^{-1}	$H_2PO_4^-$ meq L^{-1}	K^+ meq L^{-1}	Ca^{++} meq L^{-1}	SO_4^{--} meq L^{-1}	Mg^{++} meq L^{-1}	Cl^- meq L^{-1}	Na^+ meq L^{-1}	CO_3^{--} meq L^{-1}	HCO_3^- meq L^{-1}	NO_2^- meq L^{-1}	Micro mg L^{-1}	pH	EC dS m^{-1}
Well water	0.1	0.1	traces	0.1	1.2	0.2	0.6	2.4	1.6	0.0	5.2	0.0	<0.1[1]	6.9	0.8
Nutrient solution															
10 Dec.–16 Mar.	13.5	0.8	0.5	5.9	2.6	0.9	0.9	-	-	-	-	-	15[2]	5.5	2.2
17 Mar.–27 Jun.	12.9	0.8	0.6	6.5	2.5	1.1	0.9	-	-	-	-	-	17[2]	5.5	2.2

[1] Cu, Mn, Fe, Zn and B
[2] nutrient solution prepared with Micro Integral® (Cualin, Integral S.A.): Fe 7% (EDTA and EDDHA); Cu 0.4% (EDTA); Mn 3.8% (EDTA); Zn 0.6% (EDTA); B 0.7% (mineral) and Mo 0.3% (mineral)

Table 2- Properties of the growing media (compost properties were determined before and after the culture)

	water retention (% v/v)										CEC[11], (meq per)		
	AC[1]	EAW[2]	BC[3]	UW[4]	AW[5]	TW[6]	TPS[7]	pd[8] (g cm^{-3})	bd[9] (g cm^{-3})	VS[10] (%)	100 g DM[12]	100 g VS[10]	L
Grape marc													

compost													
before	59.0	1.2	1.0	23.7	2.2	25.9	84.3	1.503	0.236	92.3	113	123	267
after	50.6	3.7	2.1	28.6	5.7	34.3	84.9	1.505	0.227	91.9	121	127	274
Pine barc compost													
before	32.0	10.3	3.0	39.6	13.4	53.0	85.0	1.517	0.228	90.2	125	131	285
after	38.6	7.7	3.2	37.1	11.1	48.0	86.6	1.533	0.206	88.1	122	128	251
Rockwool[13]	14.9	77.8[14]		4.0	77.8	81.8	96.7	-	0.090	-	-	-	-

[1] AC, air capacity; [2] EAW, easily available water; [3] BC, buffering capacity; [4] UW, unavailable water; [5] AW, available water (includes EAW and BC); [6] TW, total water; [7] TPS, total pore space; [8] pd, particle density; [9]bd, bulk density; [10] VS, volatile solids; [11] CEC, cation exchange capacity; [12]DM, dry matter; [13] manufacturer data; [14] EAW + BC.

Table 3 - Temperatures of the substrates (*italic*: substrate mean temperature below lower mean air temperature)

	Temperature means (greenhouse)				Difference to air mean temperature			Difference to rockwool mean temperature	
Month	Air	RW[1]	GMC[2]	PBC[3]	RW	GM	PB	Grape marc compost	Pine bark compost
Jan	17.1	20.3	18.8	17.8	+3.2	+1.7	+0.7	-1.5	-2.5
Feb	17.9	19.4	18.4	*17.7*	+1.6	+0.5	-0.2	-1.1	-1.7
Mar	18.7	19.5	*18.4*	*18.4*	+0.8	-0.2	-0.4	-1.1	-1.2
Apr	18.3	*17.2*	*17.4*	*17.7*	-1.1	-0.8	-0.6	+0.2	+0.4
Mai	20.8	*19.4*	*20.1*	*20.6*	-1.4	-0.6	-0.2	+0.7	+1.2
Jun	23.1	*21.9*	*22.8*	*23.1*	-1.2	-0.4	-0.0	+0.9	+1.2

[1] RW, rockwool; [2] GMC, grape marc compost; [3] PBC, pine bark compost.

Table 4 – Tomato fruit yield, number and mean fruit weight

	Fruit yield (kg m^{-2})					Fruit number					Mean fruit weight
Substrate	Extra	Class I	Class II	Commercial	Total	Extra	Class I	Class II	Commercial	Total	(g)
Early production											
RW[1]	0.62	2.19	1.85	4.64	5.11	2.59	10.9	9.94	23.4	27.1	184
GMC[2]	0.68	1.80	1.74	4.21	4.89	2.72	8.77	9.57	21.1	26.9	187
PBC[3]	0.38	1.52	1.99	3.88	4.59	1.67	7.41	10.5	19.6	25.6	183
ANOVA[4]	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s
Total production											
RW[1]	3.6	6.9	5.5	16.2	17.4	13.8	30.4	26.2	70.4	81.4	216
GMC[2]	4.0	7.1	5.5	16.6	17.9	15.3	30.2	25.9	71.4	82.2	217
PBC[3]	2.9	6.7	5.8	15.5	19.9	11.3	28.0	27.7	67.0	78.7	215
ANOVA[4]	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s

[1] RW, rockwool; [2] GMC, grape marc compost; [3] PBC, pine bark compost

[4] Significance: n.s, not significant for $p \leq 0.05$

Table 5 - Tomato yield on the different substrates, in successive years

				Fruit yield (kg m^{-2})				
Substrate	Crop	System	Heating	Extra	Class I	Class II	Commercial	Total
RW[1]	1st	closed	yes	3.9	6.5	5.2	15.6	16.6
		open	yes	3.6	6.9	5.5	16.2	17.4
		open	no	-	-	-	17.3*	20.6*
	2nd	closed	yes	0.88	3.8	8.6	13.2	15.9
		open	no				8.3	13.7

	3rd	open	no	2.12	4.51	7.65	14.3	16.3*
GMC[2]	1st	open	yes	4.0	7.1	5.5	16.6	17.9
	2nd	closed	yes	0.44	3.6	8.3	12.3	14.9
		open	no	-	-	-	6.3	11.3
	3rd	open	no	1.7	4.0	7.2	12.9	15.1*
PBC[3]	1st	open	yes	2.9	6.7	5.8	15.5	19.9
	2nd	open	no	-	-	-	7.5	12.3
	3rd	open	no	3.3	5.4	8.4	17.1	19.3

[1] RW, rockwool; [2] GMC, grape marc compost; [3] PBC, pine bark compost

Table 6 – Tomato fruit quality

		Parameter[a]						
Observation	Substrate	pH	° Brix	total acidity (g cm^{-3})	nitrates (mg kg^{-1})	dry matter (%)	ashes (%)	maturation index
First	Rockwool	4.07	4.30	0.357	307	5.87	0.420	12.1
	Grape marc compost	4.13	4.43	0.333	289	5.93	0.427	13.3
	Pine bark compost	4.14	4.37	0.343	303	5.80	0.437	13.2
	ANOVA	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Second	Rockwool	4.08	4.87	0.403	312	6.40	44.3	53.0
	Grape marc compost	4.08	5.17	0.423	377	6.73	58.0	50.5
	Pine bark compost	4.10	5.33	0.380	353	6.97	44.7	59.2
	ANOVA	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Third	Rockwool	4.15	4.67	0.340b	291	6.17	41.3	13.9
	Grape marc compost	4.18	4.83	0.333b	309	6.43	42.0	14.7
	Pine bark compost	4.21	4.40	0.267a	324	6.00	38.3	16.0
	ANOVA	n.s.	n.s.	**	n.s.	n.s.	n.s.	n.s.

[a] Means within a column followed by different letters are significantly different at 5% level according to Duncan's Multiple Range Test

[b] n.s, not significant for $p \leq 0.05$; **, significant for $p \leq 0.01$.

Figures

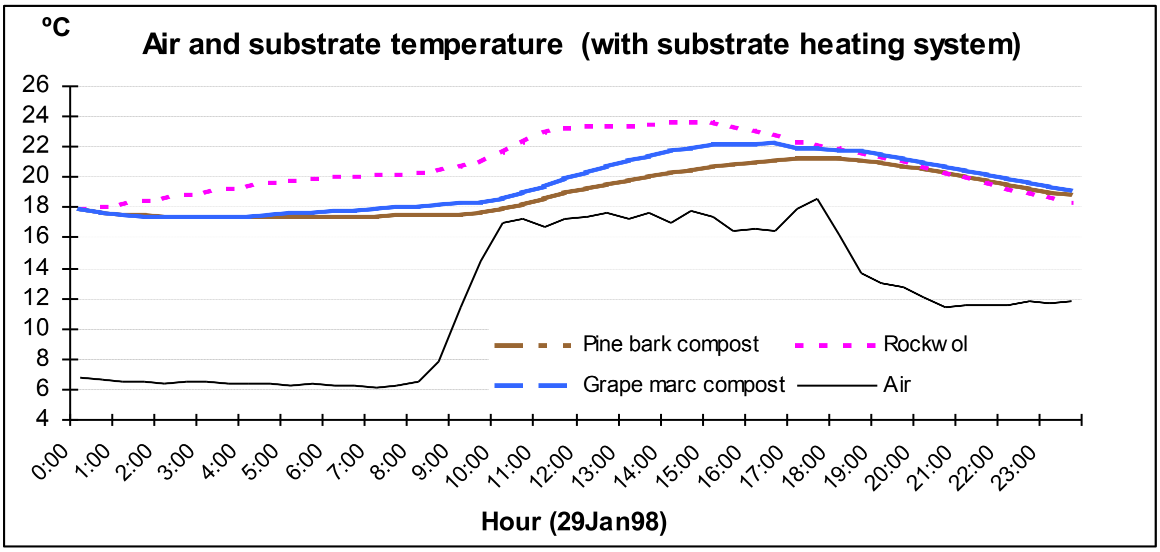

Figure 1 - Mean air and temperature during the coldest day of the trial, in the substrates with heating system

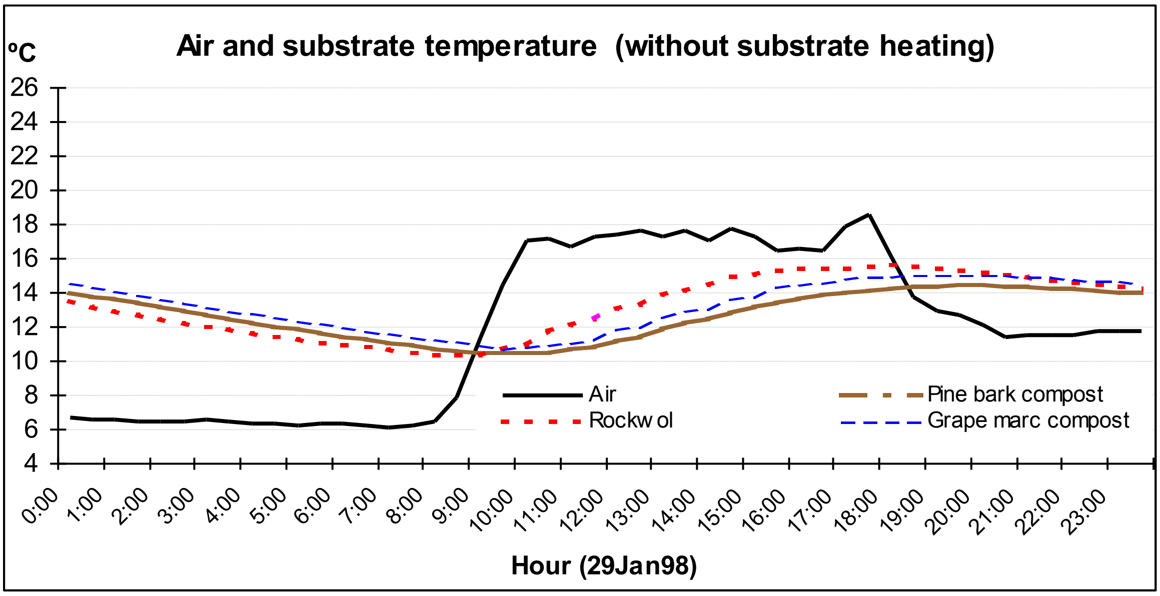

Figure 2 - Mean air and temperature during the coldest day of the trial, in the substrates without heating system