

GRAPE MARC COMPOST AS AN ALTERNATIVE GROWING MEDIA FOR GREENHOUSE TOMATO¹

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Abstract

The present work compares grape marc compost (GMC) with rockwool (RW) as a substrate for greenhouse tomato production in open and closed systems. GMC exhibited a high total pore space (84.3 v/v) and air capacity (59.0% v/v) but a low easily available water (1.2% v/v). Most of the total water content (25.9% v/v) of GMC was retained under a tension above 100 cm of water column (23.7% v/v). Rockwool (Grodan[®]) has a higher total pore space (96.7%) and total water retention (81.8%), most of it (77.8%) retained between 10 and 100 cm of water column, but a lower air capacity (14.9%). Tomato 'Sinatra' (Sluis & Groot, Holland) was grown on 15 L rockwool slabs and on 30 L compost bags, in a heated plastic greenhouse, from November to June, in two consecutive years. In the first year (1997/98) tomato production was compared on RW (open and closed systems) and on GMC (open system). No significant differences were observed in commercial yield on RW (15.6 kg m⁻² and 16.2 kg m⁻², respectively in closed and open system) and on GMC (16.6 kg m⁻², open system). In the second year (1998/99) RW and GMC were used on a closed system and tomato yield was compared using new substrates (1st crop) and substrate from the previous year (2nd crop). Commercial yield reached the standard of the region and no significant differences in between RW and GMC, and between 1st crop substrate (new substrate) and 2nd crop substrate (reused substrate). The results show that grape marc compost can be used as a rockwool substitute for greenhouse tomato production in open and in closed systems.

1. Introduction

Salinization and soil born diseases have increased the interest for soilless culture in the region of Algarve (south Portugal) where growers use mostly rockwool, coco fibre and perlite (Rosa, 1999). Recycling greenhouse effluents can save water and fertilisers, alleviate pollution and increase yield and fruit quality (Bar-Yosef, 1999), being a major objective in soilless cultivation (van Os, 1999; Runia *et al.*, 1999), which is already compulsory in Holland (Krej and Jonsson, 1999). Most of the experience with recycling solutions is concerned with the use of inorganic substrates but economical and environmental restrictions related to the use of rockwool (Benoit, 1990) have generated an interest for alternative materials (Pudelski, 1987; Abad *et al.*, 1993). Grape marc is easily available in Portugal. Its compost is suitable to be used as growing media for seedlings and pot plant production (Reis, 1997; Reis *et al.*, 1999). However the use of grape marc compost in growing bags has not been tested yet.

The objective of this work was to test grape marc compost as an alternative to rockwool in greenhouse tomato production, in closed and in open circulating systems.

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2. Material and methods

2.1. Substrates

Grape marc was obtained from a local winery (Adega Cooperativa de Lagoa) and composted for three months in a windrow, after the addition of 1 kg m^{-3} of nitrogen (urea). Grape marc compost (GMC) was used in 30 L polyethylene bags ($1 \times \text{Ø } 0.2 \text{ m}$). Physical and chemical properties of GMC were determined (1). 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.* method (1974). 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.* method (1974), 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 °C . Cation exchange capacity (CEC) was determined according to Harada and Inoko's method (1979). Volatile solids (VS) were determined by calcination of milled dry sample at 560°C for 3 h (Ramos *et al.*, 1987).

Rockwool (RW) (Grodan[®], Grodan B.V., Holland) was used in 15 L slabs ($1 \times 0.1 \times 0.015 \text{ m}$, wrapped, two years).

2.2. Cultivation system

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

Low cost gutters were made with black polyethylene film and polystyrene slabs. In each row a polyethylene film was laid on the ground and a line of polystyrene slabs was laid over the film. Substrate containers were placed on the polystyrene slabs, and the polyethylene film was rolled around the containers and fixed with wire pieces. Two heating pipes were placed inside the gutter, one pipe on each side of the substrate containers. Three self-compensating and anti leak emitters (3 L h^{-1} , PLASTRO CNL) were used per container.

Water taken from a well was used for irrigation (2). Two 500 L fertiliser tanks were used for A and B nutrient solutions, plus a third 350 L tank for the acid solution (HNO_3). Different nutrient solutions were used along the cropping cycle (2). A fertilizer-/irrigation computer (AMI 1000, DGT Volmatic, Denmark) was used to prepare and control the nutrient solution. Irrigation period was pre-set and irrigation frequency was controlled by accumulation of solar radiation. 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 ($2.2 \text{ plants m}^{-2}$).

Closed system

In the closed system, drainage solution was collected in the gutters, driven to a buried tank (200 L), and automatically pumped to the drainage reservoir (3000 L). If the volume of the drainage solution in this drainage reservoir decreased from a pre-set low level fresh water was automatically added into the reservoir. When the next irrigation occurred, the mix in the drainage reservoir (drainage plus well water) was pumped, filtered through sand and mesh filters, UV sterilised (WR 10, Rex Ibérica S.A., Spain), and used to prepare the new irrigation solution, according to the fixed EC value. Whenever the EC in the drainage reservoir exceeded 1.8 dS m^{-1} the drainage coming from the buried tank was not accepted (it was rejected and not going into the drainage reservoir). The percentage of rejected solution (lost water) was determined by the relation between the volume of rejected

solution and the volume of fresh water coming from the well. In the second year of the experiment, drainage water from rockwool and grape marc was collected together.

The automatic control of irrigation was based on the volume of drainage in RW, which was kept between 20 and 40% by varying the frequency (adjusting the value of radiation accumulation that would start a new irrigation), and/ or the irrigation period.

Open system

In the open system the main system was the same, except for the drainage water that was not recycled. The nutrient solution was made with fresh water only. The volume of drainage was kept between 20 and 30% in RW.

2.3. Tomato growing trials

1st year

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

Tomato was grown from 12.12.97 to 27.06.98. Fruits were collected twice a week and graded into classes: Extra, Class I, Class II and Not commercial (CEE, 1990). Fruit in classes Extra, I and II were designated as commercial production.

The experiments were laid out using a complete randomised block design: 3 growing conditions x 3 replicates. Fruit yield and number was 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.)

2nd year

Tomatoes were grown in a closed system, using RW and GMC in their first crop (new substrate) and second crop (reused substrate).

Tomatoes were grown from 19.11.98 to 28.06.99. Fruits were collected twice a week and graded into classes as in the previous year.

The experiment was laid out using a complete randomised block design: 4 growing conditions x 3 replicates. Fruit yield and number were determined and analysed as in the 1st year.

3. Results and discussion

3.1 Substrate properties

Grape marc compost is a coarse material, with a high total pore space (84.3 v/v) and air capacity (59.0% v/v) but low easily available water content (1.2% v/v). Most of the total water content of grape marc compost (25.9%) is retained under a tension above 100 cm of a water column (23.7% v/v of 25.9% v/v) (1). Rockwool has a high total pore space (96.7%) but a much lower air capacity (14.9% v/v) than GMC (1). Most of the water of RW (81.8% v/v) is retained under a tension between 10 and 100 cm of a water column (77.8% v/v of 81.8% v/v).

In spite of GMC lower water content at low tensions, fruit yield on GMC and on RW was similar (Table 3). This good result on GMC was probably related to the high frequency of irrigation, and to some extent to the higher volume of substrate when GMC was used. During the trial, irrigation frequency increased from 3 times day⁻¹ at the start to about 30 times day⁻¹ in the warmest period. This high irrigation frequency would allow for a sufficient refill of the short water holding capacity of GMC. In addition, due to the higher volume of substrate in GMC bags, there was an increased water reserve. In GMC bags the available water was only 5.7% of the available water in RW slabs, but the total water reached 63,3% of the total water in RW slabs. This might indicate the importance of water retained at a tension above 100 cm of water column on tomato growth.

3.2 Tomato yield

The growing system (open or closed) did not influenced fruit yield, which was high according to the standard of the region (Rosa, 1999).

In the 1st year, no significant differences were observed in tomato production (fruit yield and number per class) between RW and GMC in the open system, and RW in the closed system (Table 3).

In the 2nd year, again no significant differences in yield were observed between RW and GMC in closed system, both on first and second crop substrates (Table 3).

These results indicate that there is no restriction on the use of GMC as substrate, even when used in a second crop.

3.3 Growing system

Cultivation on grape marc compost in the open system was conducted according to the usual procedures for rockwool. A more accurate control of the nutrient solution in the closed system with GMC is needed than when using inert materials as substrate.

In spite of grape marc compost low water-retention, the tomato fruit yield in the closed system was comparable to the values observed on rockwool.

In the open system, in 1st year trial, the percentage of drainage was about 37% of the applied nutrient solution (4). In the 2nd year trial, the closed system with GMC and RW, allowed a significant reduction in water consumption. The estimation of the volume of the solution lost during the growing period (including drainage automatically rejected and the lost solution due to maintenance operations), indicated a water lost of only 5.7% of the total fresh water that entered the system (5), which represents a considerable economy in water and nutrients when compared to a usual runoff of 20 to 40% in a open system.

Both grape marc compost and rockwool produced similar fruit yield when used on a second crop.

These good performances open interesting perspectives for the use of grape marc compost as an alternative to rockwool in tomato production in closed systems. It is even possible to improve the performance of GMC by further research to optimise the watering and fertilising methods for this novel substrate.

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Tables

1. Growing media properties

	water retention (% w/w)							pd ⁹ (g cm ⁻³)	bd ¹⁰ (g cm ⁻³)	VS ¹¹ (%)	CEC ¹² , (meq per)		
	AC ¹	EAW ²	BC ³	UW ⁴	AW ⁵	TW ⁶	TPS ⁷				100 g DM ¹³	100 g VS ¹¹	L
Grape marc compost	59.0	1.2	1.0	23.7	2.2	25.9	84.3	1.503	0.236	92.3	113	123	267
Rockwool ¹⁴	14.9	77.8 ¹⁵	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 includes EAW and BC.

2. Ion content the irrigation water (well) and the standard nutrient solutions

	NO ₃ ⁻	NH ₄ ⁺	H ₂ PO ₄ ⁻	K ⁺	Ca ⁺⁺	SO ₄ ⁻	Mg ⁺⁺	Cl ⁻	Na ⁺	CO ₃ ⁻	HCO ₃ ⁻	NO ₂ ⁻	Micro	pH	EC
	meq L ⁻¹	meq L ⁻¹	meq L ⁻¹	meq L ⁻¹	meq L ⁻¹	meq L ⁻¹	meq L ⁻¹	meq L ⁻¹	meq L ⁻¹	meq L ⁻¹	meq L ⁻¹	meq L ⁻¹	mg L ⁻¹		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
1st trial - 1997/8															
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
2nd trial - 1998/9															
6 Nov.–2 Feb.	13.5	0.8	0.5	5.9	2.6	0.9	0.9	-	-	-	-	-	15 ²	5.5	2.2
3 Feb.–23 Mar.	14.4	0.6	0.6	6.9	2.4	1.1	1.0	-	-	-	-	-	15 ²	5.5	2.2
24 Mar.–28 Jun.	12.5	0.7	0.6	5.0	2.3	0.8	1.0	-	-	-	-	-	15 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)

3. Tomato yield

Substrate System	Fruit yield (kg m ⁻²)					Fruit number					Mean fruit weight (g)	
	Extra	Class I	Class II	Commercial	Total	Extra	Class I	Class II	Commercial	Total		
(1st trial - 1997/98)												
RW ¹ Open	3.9	6.5	5.2	15.6	16.7	15.1	27.4	24.1	66.5	75.2	219	
RW ¹ Closed	3.6	6.9	5.7	16.2	17.4	13.8	30.4	26.2	70.4	81.4	216	
GMC ² Open	4.0	7.1	5.5	16.6	17.9	15.4	30.2	25.9	71.5	82.2	217	
ANOVA ³	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s	
(2nd trial - 1998/99)												
RW ¹ First	0.57	3.1	8.7	12.3	15.1	2.1	13.0	45.4	60.6	85.2	169	
RW ¹ Second	0.88	3.8	8.6	13.2	15.9	3.2	15.6	43.5	62.2	87.8	175	
GMC ² First	0.51	3.3	9.2	13.0	16.4	1.9	14.0	48.3	64.2	95.9	164	
GMC ² Second	0.44	3.6	8.3	12.3	14.9	1.7	15.3	43.2	60.0	84.9	169	
ANOVA ³	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 Significance: n.s, not significant for p ≤ 0.05

4. Nutrient solution during the 1st trial (1997/98)

(mean values)		Treatments		
		Rockwool		Grape marc compost
		recycling system	open system	open system
Applied	L m ⁻² day ⁻¹	3.65	3.06	3.06
	EC (dS m ⁻¹)	2.1	2.1	2.2
	pH	6.4	6.4	6.3
Drained	L m ⁻² day ⁻¹	1.6	1.2	1.1
	%	44	38	36
	EC (dS m ⁻¹)	2.5	2.9	3.1
	pH	6.6	6.6	6.6
Lost	L m ⁻² day ⁻¹	0.1	1.2	1.1
	%	2.8	38	36

5. Nutrient solution during the 2nd trial (1998/99)

(mean values)		Treatments (recycling system)			
		Rockwool		Grape marc compost	
		1 st crop (new substrate)	2 nd crop (reused substrate)	1 st crop (new substrate)	2 nd crop (reused substrate)
Applied	L m ⁻² day ⁻¹	2.51	2.51	2.51	2.51
	EC (dS m ⁻¹)	2.1	2.1	2.1	2.1
	pH	6.4	6.4	6.4	6.4
Drained	L m ⁻² day ⁻¹	0.98	0.85	0.93	0.95
	%	39	34	37	38
	EC (dS m ⁻¹)	2.6	2.7	3.3	2.6
	pH	7.0	7.0	7.2	7.0
Lost ¹	L m ⁻² day ⁻¹	0.12	0.12	0.12	0.12
	%	5.7	5.7	5.7	5.7

¹ Includes the solution automatically rejected from recycling and the solution lost during the maintenance operations of the system