Evaluation of organic fertilization with composts in the production of grafted tomatoes with different pruning systems

Isabel Mourão[1*], Luis Miguel Brito[1], João Coutinho[2]
(1) Mountain Research Centre (CIMO), Escola Superior Agrária, Instituto Politécnico de Viana do Castelo, Refóios, 4990-706 Ponte de Lima, PT
(2) C. Química, DeBA, EC Vida e Ambiente, Universidade de Trás-os-Montes e Alto Douro, ap 1013, 5001-911 Vila Real, PT
*Corresponding author: isabelmourao@esa.ipvc.pt

Abstract
The effects of composts of the source-separated organic fraction of municipal solid wastes in combination with different pruning systems were evaluated on yield and quality of grafted tomato crop. The experiment was conducted in spring/summer season, under greenhouse conditions at NW Portugal, with a split-plot experimental design, with three blocks. The large plots included three composts: certified for organic production, standard and standard with pine bark at a rate of 7.3 t ha^{-1}, and zero compost. The small plots included two pruning systems: double and triple stem. The total yield was not significantly different between crops grown without and with the soil application of the three composts. However, fruits grown with compost were firmer and less acid compared to fruits grown without compost, and for the fruit grade > 102 mm, which represented 76% of total yield, the double stem plants showed an increased yield (14.5 kg m^{-2}), compared to the triple stem (13.5 kg m^{-2}).

Introduction
Excessive use of mineral fertilizers on agricultural land is a major cause of groundwater contamination [1] and highly contributes to increase greenhouse gases emissions [2] consequently consumers show a growing interest in food quality and its production system. The use of composts is an alternative to the synthetic fertilizers in protected horticultural crops, particularly in organic production and in areas where there are restrictions to mineral fertilizers application. The benefits of soil incorporation of organic matter (OM) are well known, either concerning the physical and chemical soil properties [3], or increasing enzyme activity, microbial biomass [4] and specific beneficial organisms.
Intensification of vegetable crop production has also contributed to increased incidence of soil pests and diseases, a problem that can be mitigated by vegetable grafting, including tomato. The grafting induce to resistance/tolerance to various soil diseases [5], such as *Pyrenochaeta lycopersici*, *Fusarium oxysporum* f. sp. *lycopersici*, *Ralstonia solanacearum*, *Verticillium albo-atrum* and may also provide resistance to nematodes [6]. Moreover, the use of a vigorous rootstock induces strong plants, which allows lower planting density without sacrificing productivity and also to maintain production for several months as it is usual in hydroponic crops of tomato, pepper, eggplant and cucumber [7]. The absorption and/or the efficiency of nutrients utilization by plants may be improved by grafting with certain rootstocks, which allows for lower application of chemical fertilizers, as well as may induce tolerance to salinity or alleviate nutrient stress symptoms [8, 9]. The grafting in tomato may also contribute to increase fruit quality under multiple and combined stress conditions [10]. This study aimed to evaluate the effects on yield and quality of tomatoes, of the soil application of different composts and two pruning systems of grafted tomato plants, which is used strategically to prevent the incidence of soil diseases.

Material and Methods
The experiment was conducted in spring/summer under greenhouse conditions, at NW Portugal (41º20'41.6"N, 8º28'18.4"). The soil was a cambisol with a sandy loam texture and some chemical characteristics are presented in Table 1. The experimental design was a split-plot, with three blocks and 8 treatments. The large plots included treatments with the three composts of the source-separated organic fraction of municipal solid wastes (C1: certified for organic production, C2: standard and C3: standard with pine bark) applied at a rate of 7.3 t ha^{-1} and without compost (control). The small plots included two pruning systems: double and triple stem.

Table 1. Soil characteristics of the greenhouse.

pH H_2O	CE (dS m^{-1})	MO (g kg^{-1})	P_2O_5 ER*	K_2O ER*	Ca	Mg
			(mg kg^{-1})			
5.8	1.2	44.0	900.0	691.0	808.0	148.0

* ER - Egner-Rhiem method.

The compost materials of the source-separated organic fraction of municipal solid wastes had the following composition, in similar proportions (v/v): (i) organic waste from restaurants, hotels, bars, canteens, markets, agricultural cooperatives, fruit and vegetables distribution centres; (ii) green waste from pruning and cleaning of gardens, parks, cemeteries; and (iii) waste materials discarded by the sieves in the recirculation process, especially large woody materials. For compost 3, about 8% (w/w) of pine bark were included in the mixture.

The tomato cv. Valoásis M40 F1 was grafted on the inter-specific (*Solanum lycopersicum* L.×*Solanum habrochaites* S. Knapp & D.M. Spooner) rootstocks Maxiforte F1. The spacing between stems was 0.5 m and between lines was 0.8 m, resulting in a plant density of 1.25 and 0.83 plants m^{-2}, respectively for plants with 2 and 3 stems. The soil was covered with a fabric film and the nylon strip tutors were 2.5 m in height. The plant protection included the application of the predator *Nesidiocoris tenui* (Heteroptera: Miridae) to control 45 days after planting; sulphur for control the mite *Aculops lycopersici*, compatible with the auxiliary *N. tenui* and the N-tiotrihalometil (Folpec WG, Sapec) against mildew. The irrigation was performed by drip system and it was used bumblebees (*Bombus terrestre*, Beeline bb Bioline Syngenta). The first harvest occurred on 15th June (84 days after planting) and the last harvest on 20th September (181 days after planting). Over this period of 97 days 15 harvests were performed weekly, in two plants for each repetition of all treatments. It was recorded the number of fruits and fresh weight for each of the following grades: ≤ 57, 58-67, 68-82, 83-102 and > 102 mm. The firmness, pH, total soluble solids content, titratable acidity and dry weight were evaluated for four crops during the harvest period for treatments without compost and with the compost C1. The fruit firmness was determined with a penetrometer (TR Snc), the soluble solids with an ABBE refractometer (Vitrilab), the pH with a potentiometer and the acidity was determined by titration to pH 8.1 with a solution of 0.1N NaOH, in the presence of phenolphthalein and was expressed as a percentage of citric acid. The dry matter was determined after drying the fruit in a ventilated oven at 70 ° C for 48 hours.

Compost DM content, pH, electrical conductivity (EC), OM content and $N_{Kjeldahl}$ were determined by standard procedures [6] and compost mineral N was analysed by molecular absorption spectroscopy, after extraction with 2 M KCl.

The analysis of variance procedure and Least Significant Difference test was applied to test for significant differences between mean data. Both forms of statistical analysis were carried out using SPSS 17.0 for Windows (SPSS Inc.). A probability level of α=0.05 was applied to determine statistical significance.

Results

The compost characteristics (Table 2) showed that C1 was well matured and C2 was less matured with higher contents of NH_4^+-N and Mg and lower contents of P and Ca, compared to the others. The compost C3, which resulted from the addition of pine bark to the original materials used in the composting, had higher contents of OM, NO_3^--N and Ca, and lower pH and EC.

The number of fruits and the total yield were not significantly different either between compost treatments or between different pruning systems (Table 3). However, differences were found between fruit characteristics and commercial tomato yield. Tomato grade > 102 mm represented an average of 76% of total production and significant differences were found between crop treatments (Fig.1). For this grade, the double stem tomato crop increased total yield (14.5 kg m^{-2}), compared to plants with three stems (13.5 kg m^{-2}). Considering the unit price of grafted plants (0.70 €), the difference between plant density of double and triple plants (0.42 plants m^{-2}), the yield increase (1.1 kg m^{-2}) and the mean price of tomato (0.50 € kg^{-1}), the gross income obtained with the double stem tomato was 0.26 € m^{-2}, equivalent to 2560 € ha^{-1}.

Table 2. Dry matter (DM), organic matter (OM), pH, electrical conductivity (EC), C/N ratio, and contents of NO_3^--N, NH_4^+-N, mineral N, total N, P, K, Ca and Mg, for the three composts. Mean values ± standard deviations (n=18). Different letters on each line correspond to significant differences between the composts (P <0.05).

		C1		C2		C3	
DM	(%)	82.5±1.49	a	80.8±1.41	a	64.7±2.28	b
OM	(g kg^{-1})	610±11.3	b	640±3.1	ab	682±2.3	a
pH		8.7±0.10	a	8.7±0.06	a	7.6±0.13	b
EC	(dS m^{-1})	7.5±0.30	a	7.2±0.35	a	5.8±0.28	b
C/N		15.4±0.87	a	15.2±0.94	a	13.5±2.09	a
NO_3^--N	(mg kg^{-1})	224±116.0	b	204±19.2	b	1100±106.8	a
NH_4^+-N	(mg kg^{-1})	1221±163.5	b	2008±36.6	a	1276±194.9	b
N min	(mg kg^{-1})	1446±95.4	c	2213±53.2	b	2375±118.5	a
N_t	(g kg^{-1})	24.3±1.32	ab	23.5±1.84	b	25.1±1.34	a
P	(g kg^{-1})	5.6±0.19	a	4.9±0.13	b	5.5±0.49	a
K	(g kg^{-1})	10.3±0.49	b	20.2±5.22	a	21.2±0.42	a
Ca	(g kg^{-1})	42.2±0.34	b	37.6±0.33	c	72.5±0.48	a
Mg	(g kg-1)	1.4±0.04	c	1.7±0.06	A	1.6±0.05	b

Table 3. Mean of total number of fruits (m^{-2}) and total crop yield (kg m^{-2}) for tomato grown without compost (C0) and with the three composts (C1, C2 e C3)in double and triple stem pruning systems.

Treatments		No of fruits m^{-2}	Yield kg m^{-2}
Composts	No of stems		
C0	2	81.9	17.9
	3	79.0	16.8
C1	2	82.7	18.8
	3	83.1	17.9
C2	2	84.0	20.2
	3	85.4	19.0
C3	2	87.3	19.0
	3	81.3	18.5
LSD		*17.4*	*4.8*

Fruit DM content (4.8%) was similar for all treatments and tomato nutrient content was also not significantly different either between compost treatments (C0 and C1) or between different pruning systems (Table 4). The content of soluble solids (mean 3.5° Brix) and pH (mean 4.0), were similar between crop treatments. However, the fruit firmness of crops grown without organic fertilization and with 3 stems (1.8 kg) was lower than the firmness of the fruits grown with C1 (mean 2.1 kg) and the acidity was lower in tomatoes grown with C1 and conducted in 2 stems (0.51 g 100g) compared to fruits grown without compost application (mean 0.61 g 100g).

Conclusion and perspectives

Nutrient availability from composts did not significantly increase tomato yield, probably due to the high soil fertility of the greenhouse. However, fruit quality was improved with compost application, producing firmer fruits and with lower total acidity. The benefit of higher yield (fruit grade > 102 mm) in the double-stem tomato crop offset the increased cost of the plants needed, compared to three-stem crop.

Perspectives include the evaluation of sustainable fertilization strategies with organic fertilizers in greenhouse horticulture, as emissions of nutrients and its footprint should be reduced and evaluation of vegetable grafting to improve yield and fruit quality under biotic and abiotic stress conditions.

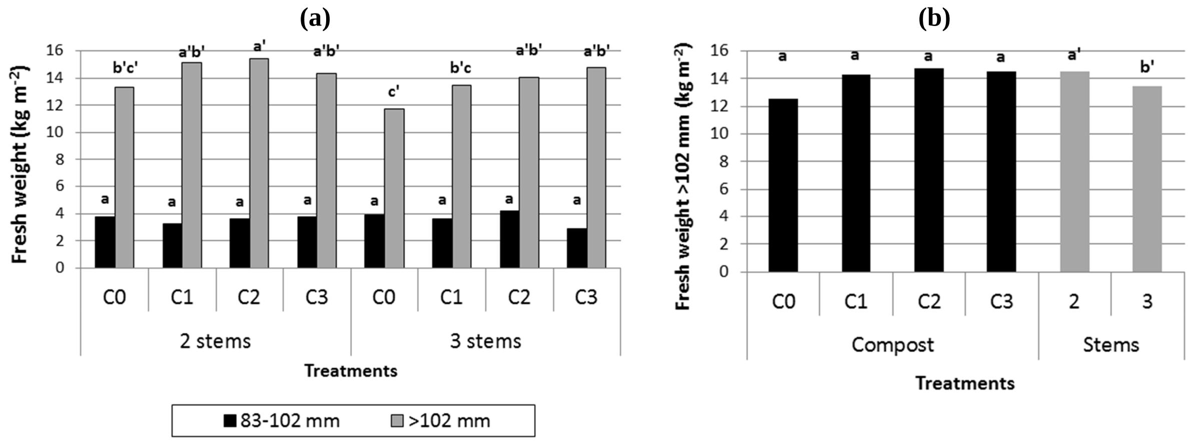

Figure 1. Tomato fresh weight (kg m-^{2}) for (a) fruit grade 83-102 and >102 mm, for the crops grown without compost (C0) and with the three composts (C1, C2 e C3), pruned with double and triple stems, and for (b) fruit grade >102 mm. Different letters for the same series means significant differences between crop treatments (p <0,05).

Table 4. Tomato nutrient content in the dry matter (DM) for the crop grown without compost (C0) and with the composts C1, and for the double and triple stem pruning systems. ns: non significant differences between treatments (P <0.05).

		N	K	P	Ca	Mg	Fe
		g/100g DM		mg/100g DM			
Compost	C0	1.96 ns	2,70 ns	173,29 ns	324,98 ns	160,83 ns	9,30 ns
	C1	1.94	2,78	169,17	332,68	177,91	8,38
Stems	2	1.97	2,67	171,09	338,40	171,75	8,35
	3	1.94	2,82	171,37	319,26	166,99	9,32

References

[1] Ten Berge HFM, 2002. A review of potential indicators for nitrate loss from cropping systems in the Netherlands. Plant Research International, Wageningen, the Netherlands.

[2] FAO, 2011. Organic agriculture and climate change mitigation. A report of the round table on organic agriculture and climate change, Rome, Italy.

[3] Makinde EA, Eniola HT, Fagbola O, 2009. Effect of organic, organomineral and NPK fertilizers on soil pH, organic matter and micronutrient content in two soil types in Nigeria. Research on Crops 10, 77-85.

[4] Gaofei G, Zhaojun L, Fenliang F, Guixin C, Zhenan H, Yongchao L. 2009. Soil biological activity and their seasonal variations in response to long-term application of organic and inorganic fertilizers. Plant and Soil 326, 31-44.

[5] Louws FJ, Rivard CL, Kubota C, 2010. Grafting fruiting vegetables to manage soilborne pathogens, foliar pathogens, arthropods and weeds. Scientia Horticulturae 127, 127-146.

[6] Rumbos CI, Khah EM, Sabir N, 2011. Response of local and commercial tomato cultivars and rootstocks to *Meloidogyne javanica* infestation. Australian Journal of Crop Science 5, 1388-1395.

[7] Davis AR, Perkins-Veazie P, Sakata Y, López-Galarza S, Maroto JV, Lee SG, Huh YC, Sun Z, Miguel A, King SR, Cohen R, Lee JM, 2008. Cucurbit Grafting. Critical Reviews in Plant Sciences 27, 50-74.

[8] Colla G, Suarez CMC, Cardarelli M, Rouphael Y, 2010. Improving nitrogen use efficiency in melon by grafting. Hortscience 45, 559-565.

[9] Savvas D, Savva A, Ntatsi G, Ropokis A, Karapanos I, Krumbein A, Olympios C, 2011. Effects of three commercial rootstocks on mineral nutrition, fruit yield and quality in salinised tomatoes. Journal of Plant Nutrition and Soil Science 174, 154-162.

[10] Rouphael Y, Schwarz D, Krumbein A, Colla G, 2010. Impact of grafting on product quality of fruit vegetables. Scientia Horticulturae 127, 172-179.