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Nutritional status, yield and composition of peach fruit subjected to the application of organic compost

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ABSTRACT. The purpose of this study was to evaluate the nutritional state, yield and composition of peaches on peach trees subjected to the application of organic compost to the soil. This experiment was conducted during the 2008 and 2009 cropping season in an orchard containing Chimarrita cultivars grafted onto Capdeboscq rootstocks and Haplumbrept soils in the municipality of Farroupilha (Rio Grande do Sul State), Brazil. The treatments included 0, 9, 18, 36, 72 and 144 liters of organic compost per plant^{-1} year^{-1}. The total nutrient contents in the leaves, yield components, yields per plant and hectare and compositions of the fruits were evaluated in 2008 and 2009 soon after harvest and after 30 days of storage. The application of organic compost to the soil increased the yield components and the yields per plant and hectare in the two treatments with the highest compost additions, which indicated that the addition of 72 L of compost per plant^{-1} is ideal economically. The organic compost had little effect on the composition of the peach fruit after harvest and after 30 days of storage.

Keywords: mineral nutrition, organic waste, *Prunus persica*.

Estado nutricional, produção e composição de frutos de pessegueiros submetidos à aplicação de composto orgânico

RESUMO. O objetivo do trabalho foi avaliar o estado nutricional, produção e composição de pêssegos em pessegueiros submetidos à aplicação de composto orgânico no solo. O experimento foi conduzido, na safra 2008 e 2009, em um pomar da cultivar Chimarrita, enxertada sobre o porta-enxerto Capdeboscq e cultivadas em um solo Cambissolo Húmico, no município de Farroupilha (Estado do Rio Grande do Sul). Os tratamentos foram 0, 9, 18, 36, 72 e 144 litros de composto orgânico por planta^{-1} ano^{-1}. Avaliou-se o teor de nutrientes totais nas folhas, componentes de produção, produção por planta e hectare e a composição dos frutos em 2008 e 2009, logo depois da colheita e 30 dias após armazenamento. A aplicação de composto orgânico no solo, aumenta os valores de componentes de produção e a produção de pêssego por planta e hectare, nas duas maiores quantidades de composto fornecidas, o que economicamente indica a melhor dose de 72 L de composto por planta^{-1}. A adição de composto orgânico na superfície do solo não afeta o estado nutricional e pouco afeta a composição dos pêssegos após a colheita e depois de 30 dias do armazenamento.

Palavras-chave: nutrição mineral, resíduos orgânicos, *Prunus persica*.

Introduction

Organic compost has been used as a source of nutrients in pre-planting fertilization, fertilization during growth and, especially, fertilization for maintaining peach (*Prunus persica* [L.] Batsch) orchards in the region of the Serra Gaúcha of Rio Grande do Sul (Rio Grande do Sul State), Brazil, which is the most important region for peach production directed toward *in natura* consumption in Brazil (Brunetto, Melo, Kaminski, & Ceretta, 2007).

Compost may be obtained through aerobic composting of organic residues, such as juice lees, grape stalks, and sawdust (Hargreaves, Adl, & Warman, 2008). When applied to the soil, compost may be mineralized over time by soil microorganisms in the peach orchard, which would increase the total organic C content, the microbial biomass C content, and the metabolic activity of the microorganisms (Adani, Genevini, Ricca, Tambone, & Montoneri, 2007; Baldi et al., 2010a). The application of compost may also increase the soil porosity, which would reduce the soil density (Melo, Brunetto, Basso, & Heinzen, 2012) and increase the availability of nutrients, such as N, P, K, Ca, and Mg, in soils (Toselli, Baldi, Sorrenti, Quartieri, & Marangoni, 2010; Baldi et al., 2010a). Improving the physical, microbiological and, particularly, chemical attributes of the soil increases root production of the peach tree, particularly at the soil surface (Baldi et al., 2010a; Guo, Halliday, Siakimotu, & Gifford, 2005). These roots are responsible for uptaking the greatest quantity of water and nutrients. Thus, it is expected that an increase in the plant nutrient content could be predicted by analyzing whole leaves or fruit (Morandi, Manfrini, Losciale, Zibordi, & Corelli-Grappadelli, 2010). In addition, increases in the yield components, such as fruit weight and diameter, which reflect greater fruit yields per plant and per hectare are expected along with impacts on fruit composition, which determine the storage period after harvest (Falguera et al., 2012).

Nevertheless, the mineralization of compost in the soil will determine the responses of the peach trees and depends on the composition of the compost, including the nutrient content and C/N ratio (Jordan et al., 2011; Sofo et al., 2005). The amount of compost applied to the surface will determine the contact area with the ground, which can slow the activity of the microbial biomass (Ramos, Benítez, García, & Robles, 2011) and affect the soil moisture and soil temperature (Montanaro, Dichio, Bati, & Xiloyannis, 2012). Thus, undertaking regional field experiments, especially experiments that evaluate more than one crop season, is necessary for evaluating the effects of applying organic composts. These experiments are scarce to non-existent for the edaphic and climatic conditions of the Serra Gaúcha of Rio Grande do Sul State. The purpose of this study is to evaluate the nutritional status, yield and chemical composition of peaches from peach trees that were subjected to the application of different levels of organic compost to the soil.

Material and methods

The study was conducted in a commercial peach (*Prunus persica* [L.] Batsch) orchard of 'Chimarrita' grafted on 'Capdeboscq' rootstocks in Farroupilha (latitude 29° 07´ 08.8´´ s; longitude 51° 17´ 48,5´´ W), Rio Grande do Sul, Brazil, during the 2008 and 2009 cropping seasons. The peach tree orchard was planted in 1995 at a density of 888 plants ha^{-1} (4.5 × 2.5 m) with open-center training and four branches. The soil was classified as Haplumbrept (Soil Survey Staff, 2006), and the soil attributes were measured at a depth of 0-20 cm before the experiment was set up, as shown in Table 1. The climatic data obtained during the experiment are presented in Table 2.

Three months before planting the peach tree seedlings in 1995, 5.4 Mg ha^{-1} of dolomitic limestone was applied on the soil surface and later incorporated into the 0-20 cm layer to increase the pH in water to 6.0 (Comissão de Fertilidade do Solo [CFS], 1995).

Table 1. Physical and chemical attributes in the top 0-20 cm layer of the soil planted with 'Chimarrita' peach trees.

Attribute	Value
Clay, g kg^{-1}(1)	360
Organic matter, g kg^{-1}(2)	27
pH in water(2)	5.5
SMP Index(2)	5.6
Exchangeable Al, $cmol_c$ kg^{-1}(3)	0.0
Exchangeable Mg, $cmol_c$ kg^{-1}(3)	2.90
Exchangeable Ca, $cmol_c$ kg^{-1}(3)	5.40
Available P, mg kg^{-1}(4)	10.2
Exchangeable K, mg kg^{-1}(4)	70
Cation exchange $capacity_{pH\ 7.0}$, $cmol_c$ kg^{-1}(5)	15.4

(1)Pipette method (Empresa Brasileira de Pesquisa Agropecuária [Embrapa], 1997); (2)determined according to Tedesco, Gianello, Bissani, Bohnen and Volkweiss (1995); (3)extracted with 1 mol L^{-1} KCl (Tedesco, Gianello, Bissani, Bohnen, & Volkweiss, 1995); (4)extracted with Mehlich 1 (Tedesco et al., 1995); (5)$CEC_{pH7.0} = Ca^{+2} + Mg^{+2} + K^{+} + (H^{+} + Al^{+3})$, and $H + Al = e^{(10.665 - 1.1483SMP)}/10$.

Table 2. Rainfall, monthly mean temperature and sunlight hours during the months of the experiment.

Month of the year	Rainfall (mm)	Monthly mean air temperature (°C)	Sunlight (H)
	2008		
June	160.2	11.4	130.6
July	73.0	14.9	175.7
August	198.5	14.1	193.5
September	144.1	13.2	185.8
October	309.6	16.8	154.8
November	70.3	19.4	240.8
December	85.8	20.3	261.7
	2009		
June	82.9	11.2	155.4
July	97.8	10.2	144.9
August	257.9	15.2	183.0
September	411.7	14.6	134.4
October	145.1	16.7	194.1
November	359.5	21.6	141.1
December	232.6	21.2	224.3

In June 2008, treatments were implemented that consisted of applying 0, 9, 18, 36, 72, and 144 L of organic compost $plant^{-1}$ yr^{-1}, with totals of 0, 18, 36, 72, 144, and 288 L organic compost $plant^{-1}$ from 2008 to 2009. Organic compost was applied in approximately 1-m wide strips on the soil surface along one side of the planting row without incorporation at a distance of approximately 30 cm from the trunk.

The applied levels were established in previous experiments (unpublished data) that were conducted in a greenhouse over a 2 yr period, in which it was observed that the peach plants were taller and had greater DM production when 18 L of organic compost was added $plant^{-1}$ yr^{-1}. Thus, smaller and larger compost addition levels were established based on this reference level. The compost applied during the experiment was produced from residues derived from aerobic composting and was obtained from wineries and juice producing industries. This compost included juice lees and stems and sawdust. The initial process of row montage until compost maturation lasts approximately 200 days, depending on the size of the rows and the climatic conditions. The utilized C:N ratio was approximately 30:1, with a humidity ranging from 50 to 60% and temperatures ranging from 45 to 60°C. The mean chemical composition is show in Table 3. A randomized block experimental design was used with three replicates, and each plot was formed of five plants distributed along the row, with the three center plants being evaluated annually.

Table 3. The mean chemical composition of the organic compost applied to the soil planted with peach trees.

Variable(1)	Value
Total organic C, %	27.00
Total N, %	1.47
Total P, %	0.27
Total K, %	2.45
Total Ca, %	1.12
Total Mg, %	0.24
Total Cu, mg kg^{-1}	17.30
Total Na, mg kg^{-1}	2690.00
Total Zn, mg kg^{-1}	28.40
Total Mn, mg kg^{-1}	300.00
Total Fe, mg kg^{-1}	3512.30
Total B, mg kg^{-1}	11.20
C/N ratio	18.30
pH in water	7.00
Moisture, %	40.20

(1)Determined according to Tedesco et al. (1995).

The peach trees in the experimental area throughout the crop seasons only received organic compost as a nutrient source when necessary. In addition, under the following technical recommendations for the crops, the trees received fungicide and insecticide applications throughout the vegetative and productive cycles of the plants and during winter pruning in June. The rows where the peach trees were planted were kept free of weeds by applying a non-residual herbicide soon after senescence of the plant leaves. Between rows, spontaneous plants were maintained and were mowed when necessary.

In 2008, whole leaves were collected from the middle parts of new branches on different sides of the plants during the 14^{th} week after full flowering, which occurred in August every year, as established by Comissão de Química e Fertilidade do Solo (CQFS,RS/SC, 2004), and corresponded to one month after organic compost application. Next the leaves were dried in a laboratory using a forced air oven at 65°C until a constant weight was achieved and then analyzed for their total N, P, K, Ca, Mg, and B contents (Tedesco et al., 1995).

In 2008 and 2009 during full fruit maturation during December, the number of fruits per plant were counted. Next, all of the fruits for each plant were gathered and weighed, and the diameters of 50 randomly selected fruits per plant were measured using a digital caliper. The yield per hectare was estimated from these data. In 2008, approximately a third of the fruit collected in each treatment was analyzed for total N, P, K, Ca, and Mg (Tedesco et al., 1995). In the same crop year, the second or third fruit was crushed o determine the soluble solids contents in the juice using a portable digital refractometer (PR-101, Atago, USA) with temperature control. The total acidity was determined by using a neutralization titration with 0.1 N NaOH and phenolphthalein as an indicator. The background and coverage color were determined using a reflectometer (CM 508D, Minolta, Italy).

The last third of the fruit was pre-cooled with forced air, placed in 20 kg plastic boxes and kept in cold storage in a commercial cold chamber at -0.5±0°C and 90±5% relative humidity for 30 days. Following storage, the soluble solids, total acidity, and background and coverage colors were determined. In 2009, the collected fruits were only subjected to soluble solids and total acidity evaluations after harvest and after 30 days of storage in a cold chamber. The results were subjected to an ANOVA for each crop season, and data were fit with regression equations by using compost level as an independent variable to test the linear and quadratic models and choose the model with higher significance according to the F test.

Results and discussion

Nutritional status and fruit yield

The application of greater levels of organic compost on the soil surface did not affect the total N, P, K, Ca, Mg, and B contents in the leaves of the peach trees in 2008 (Table 4). This result potentially occurred because the leaves collected in the middle part of the new branches in the 14^{th} week after full flowering were potentially not sensitive enough to diagnose nutrient increments in the soil if they occurred. Moreover, the lack of an increase in the total nutrient contents in the leaves potentially occurred because the soil, without compost application, had 27.0 g kg^{-1} of organic matter with an average of 26.0-50.0 g kg^{-1}; 10.2 mg kg^{-1} available P with an average of 8.1-12.0 mg kg^{-1} for soils with 40 to 21% clay; and 60 mg kg^{-1} exchangeable K with an average of 41-60 mg dm^{-3}, for soils with $CEC_{pH\ 7.0}$ > 15.0 $cmol_c$ kg^{-1} according to CQFS-RS/SC (2004). Thus, an adequate availability of nutrients for the peach trees was expected.

Table 4. Total nutrient content, number, weight, and diameter of the fruits, and the yield per plant and hectare of peach trees subjected to organic compost applications.

Variable	Level of compost (L plant^{-1})						Equation	R^2
	0	9	18	36	72	144		
2008 Crop season								
Total leaf N, g kg^{-1}	22.90	24.10	24.00	23.20	23.50	24.40	ns	-
Total leaf P, g kg^{-1}	2.40	2.40	2.30	2.30	2.40	2.30	ns	-
Total leaf K, g kg^{-1}	16.90	19.30	18.00	19.00	15.90	19.40	ns	-
Total leaf Ca, g kg^{-1}	20.00	18.00	16.00	17.00	18.00	17.00	ns	-
Total leaf Mg, g kg^{-1}	4.50	4.40	4.20	4.50	4.70	4.50	ns	-
Total leaf B, g kg^{-1}	0.20	0.19	0.19	0.19	0.19	0.18	ns	-
Number of fruits per plant	176	217	179	211	239	206	$y = 180.9 + 1.23x - 0.0073x^2$	0.75*
Fruit weight, g	94.00	88.00	93.10	92.00	92.00	94.00	$y = 91.90 – 0.013x + 0.0002x^2$	0.40*
Fruit diameter, mm	51.10	52.00	55.00	54.20	55.00	55.00	$y = 51.81 + 0.084x - 0.0004x^2$	0.83*
Yield per plant, kg	16.54	19.09	16.66	19.41	21.98	19.36	$y = 16.54 + 0.1120x - 0.0006x^2$	0.84*
Yield per hectare, mg ha^{-1}	14.69	16.95	14.79	17.23	19.52	17.19	$y = 14.70+ 0.099x - 0.0006x^2$	0.84*
2009 Crop Season								
Number of fruits per plant	135	191	177	179	205	195	$y = 155.1 + 1.13x - 0.006x^2$	0.77*
Fruit weight, g	135.0	141.8	147.2	131.4	134.7	135.6	$y = 140.58 - 0.1272x + 0.0006x^2$	0.40*
Fruit diameter, mm	31.40	32.10	32.60	31.10	31.80	31.00	$y = 31.84 + 0.0008x - 4.5736E - 0.05x^2$	0.53*
Yield per plant, kg	18.30	27.10	26.10	23.60	27.60	26.40	$y = 22.02 + 0.1295x - 0.0007x^2$	0.61*
Yield per hectare, mg ha^{-1}	16.20	24.10	23.10	20.90	24.50	23.40	$y = 19.52 + 0.115x - 0.0006x^2$	0.60*

ns: Not significant at the 0.05 probability level; *significant at the 0.05 probability level according to the F test.

However, the lack of increase in the nutrient content in the leaves could also be explained by the mineralization of the compost, by runoff on the soil surface, by leaching and, in the case of N, NH_3 volatilization (Baldi, Toselli, & Marangoni, 2010c; Toselli et al., 2010) and denitrification (Baldi et al., 2010a; Rufat, Domingo, Arbonés, Pascual, & Villar, 2011). Baldi et al. (2010a) observed that the application of organic compost on the soil surface for 8 yr in peach trees grown in Italy did not affect the total nutrient content, such as N, in whole leaves. The period between the application of organic compost and leaf sampling was potentially too short to observe any changes in the total nutrient contents in the leaves (N, P, K, Ca, Mg e Bo).

The addition of increasing levels of organic compost increased the number, weight, and diameters of peaches quadratically. Consequently, the yield per plant and per hectare in 2008 and 2009 increased quadratically (Table 4). This result potentially occurred because the added compost was mineralized by microorganisms and the nutrients within the compost were released (Baldi, Toselli, Eissenstat, & Marangoni, 2010b; Ramos et al., 2011), which would increase the TOC content, mineral N, available P, and the exchangeable K, Ca, and Mg contents in the soil quadratically (unpublished data) as the addition of compost increased at 72 L compost per plant^{-1}.

Some studies showed that the application of organic compost in the soil improved the soil physical attributes by increasing the soil porosity and reducing the soil density (Erhart, Feichtinger, & Hartl, 2007; Melo et al., 2012). Thus, increases in soil nutrient availability and improvements in soil physical attributes could contribute to the improved growth of young peach tree roots, which are normally located at the soil surface and are responsible for taking up the largest quantities of soil nutrients (Baldi et al., 2010a). Therefore, a portion of the nutrients that were taken up by the plants were not observed in the leaves (Table 4), but the total N content increased linearly in the fruit as the compost level increased (Table 5). The increase of nutrients in the plants, especially N, can result in the formation of a greater number of flowers and vegetative buds on the shoots from the last vegetative cycle, which is reflected in an increase in yield components, such as fruit weight and diameter, and in the overall yield (Mattos, Freire, & Magnani, 1991). Chatzitheodorou, Sotiropoulos and Mouhtaridou (2004) also reported that the application of animal manure increased the peach yield in an orchard in Greece, which agrees with the results reported by Toselli, Baldi, Sorrenti, Quartieri and Marangoni (2010) and Baldi et al. (2010a) in an orchard in Italy subjected to the application of organic compost. It is noteworthy that, especially in the 2008 crop season, the peach fruits from all treatments had diameters of between 5 and 6 cm and weighed between 80 and 100 g (Table 4). These values are adequate and well-accepted by consumers (Medeiros & Raseira, 1998). On the other hand, during the 2009 crop season, the fruit diameter values were generally < 5 cm and weighed slightly more than 100 g (Table 4).

Table 5. Total nutrient contents, soluble solids content, total acidity, background color and coverage color of peach tree fruit subjected to organic compost applications soon after harvest and after 30 days of storage in a cold chamber.

Variable	Dose of compost (L $plant^{-1}$) 0	9	18	36	72	144	Equation	R^2
2008 Crop season								
After harvest								
Total N, mg 100^{-1} (1)	4.8	5.5	6.10	6.20	6.90	7.60	y = 5.39 + 0.017x	0.85*
Total P, mg 100^{-1} (1)	1.30	1.4	1.30	1.30	1.40	1.50	ns	-
Total K, mg 100^{-1} (1)	18.2	18.7	17.70	17.50	17.6	18.60	ns	-
Total Ca, mg 100^{-1} (1)	0.30	0.40	0.30	0.40	0.40	0.30	ns	-
Total Mg, mg 100^{-1} (1)	0.50	0.70	0.60	0.60	0.70	0.70	ns	-
Soluble solids, °Brix	9.40	9.40	10.00	9.70	9.60	10.20	ns	-
Total acidity, mol L^{-1}	7.11	7.17	7.78	6.62	6.77	7.60	ns	-
Background color (h value)	95.40	92.60	93.90	89.30	87.30	90.70	ns	-
Coverage color (h value)	31.30	34.40	32.40	33.80	34.50	33.30	ns	-
After 30 d in a cold chamber								
Soluble solids, °Brix	11.2	11.1	11.3	11.0	11.4	11.0	ns	-
Total acidity, mol L^{-1}	4.9	4.9	4.0	3.6	5.4	5.3	ns	-
Background color (h value)	88.5	86.8	81.1	86.6	92.3	91.1	ns	-
Coverage color (h value)	33.2	32.3	35.7	32.5	31.1	31.7	ns	-
2009 Crop season								
After harvest								
Soluble solids, °Brix	9.7	9.0	9.6	10.1	9.4	9.8	ns	-
Total acidity, mol L^{-1}	5.8	6.1	6.5	5.3	5.5	5.9	ns	-
After 30 days in a cold chamber								
Soluble solids, °Brix	9.7	9.4	9.9	9.2	10.0	10.6	ns	-
Total acidity, mol L^{-1}	2.9	3.2	3.1	3.3	3.6	4.2	ns	-

(1)Fresh fruit; ns: Not significant at the 0.05 probability level; *Significant at the 0.05 probability level according to the F test.

Peach composition

The application of increasing levels of organic compost to the soil increased the total N content in the fruits collected in 2008 (Table 5). This result may be explained by the quadratic increase of the mineral N content (NO_3^--N and NH_4^+-N) in the soil that was subjected to increasing levels of organic compost (data not shown), which agrees with the results reported by Baldi et al. (2010a) and Bravo et al. (2012).

A portion of the N taken up by the roots can be distributed to the fruits, which increase their DM throughout the vegetative and productive cycle of the peach tree and, consequently, serve as a N sink (Baldi et al., 2010c; Morandi et al., 2010; Rosa et al., 2009). However, during the 2008 crop season, the application of organic compost did not affect the total P, K, Ca, and Mg contents in the fruits (Table 5), which agreed with the results of the total contents in the whole leaves (Table 4).

The addition of increasing levels of organic compost to the soil did not affect the soluble solids contents (Table 5), which serve as an indicator of the quantity of sugars in the fruit, because the increase in weight and diameter of the fruit (Table 4) potentially diluted the sugars (Brunetto et al., 2007) and the total acidity, which may be one criteria for defining fruit maturity and harvest. The levels of organic compost did not affect the background color or length of the fruit soon after harvest and after 30 d of storage in a cold chamber during the 2008 and 2009 cropping seasons (Table 5). Chatzitheodorou et al. (2004) also reported that the addition of animal manure to the soil in a peach orchard did not affect the fruit acidity. In addition, Crisosto, Johnson and Dejong (1997) indicated that the application of N sources in the soil did not affect the soluble solids values in the fruit. Based on the color results, it may also be inferred that the shoots with the greatest growth in the peach trees subjected to the greatest compost levels (unpublished data) did not reduce the incidence of sun rays on the inner portions of the plants, which could delay fruit ripening (Mercier, Bussi, Plenet, & Lescourret, 2008).

However, the greatest number of fruits with incidence of brown rot (*Monilinia fructicola*) was observed in the peach trees that were subjected to the greatest amounts of compost (72 and 144 L $plant^{-1}$). This finding could be primarily associated with an increase in the N content in the fruit (Table 5) (Thomidis, Tsipouridis, & Darara, 2007), which may promote the incidence of fungal disease (Montanaro et al., 2012).

Conclusion

The application of organic compost on the soil increased the yield components and the yield per plant and hectare, especially when 72 L of compost was applied per plant, without affecting the nutrient contents in the leaves.

The addition of organic compost had few affects on the composition of the peach fruit after harvest and after 30 days of storage.

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