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SHORT COMMUNICATION

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Organic fertilization for the improvement of production and quality of ripe figs

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Abstract

Aim of study: The use of natural inputs in farming practices and the consumption of *in natura* products have been on the rise. Natural crop fertilizing sources gains force when the intent lies in crop by way of an ecologically correct agricultural system. To this end, this paper targeted assessing the use of cattle (CM) and bird manure (BM) in organic fertilization of fig culture in organic handling, and its effect on the production of ripe figs.

Area of study: Federal University of Paraná, Curitiba, Paraná, Brazil.

Material and methods: In 2011, an experimental fig orchard was established using the 'Roxo de Valinhos' cultivar. The experimental outline adopted was in randomized blocks, with 3 repetitions and 7 treatments comprised of: the control and 6 types of fertilization using CM and/or BM. Harvests were performed in 2016 and 2017. The characteristics evaluated were mean weight, length and diameter of individual fruits, mean weight and number of fruits per tree, total soluble solids content, total titratable acidity and pH.

Main results: Organic fertilization with 5 L of CM per fig tree promoted the best results in all biometric variables as compared to the plants that were not fertilized. Considering quality, only 5 L of CM or 1.25 L of BM provided equal total titratable acidity in comparison with control. Plants fertilized with 2.5 L of CM produced figs with higher maturation index against plants fertilized with 5 L of CM or 1.25 L of BM.

Research highlights: Considering the fig tree productivity and quality of ripe figs, organic fertilization with CM and BM promoted good characteristics.

Additional key words: *Ficus carica*; organic fertilizers; cattle manure; bird manure; table figs.

Abbreviations used: BM (bird manure); CM (cattle manure); FW (fruit weight); MI (maturation index); TSS (total soluble solids); TTA (total titratable acidity).

Authors' contributions: All authors conceived and designed the experiments, performed the experiments, analyzed the data, contributed reagents/materials/analysis tools, read and approved the final text. MBDT wrote the paper.

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Introduction

Fig (*Ficus carica* L.) cropping represents an important agricultural and economic activity around the world as a driver of income, employment and food. Brazil is the second largest exporter of the *in natura* fruit (Silva *et al.*, 2018), and produced 26,910 t of figs in 2016. Recently, Brazilian fig production has decreased to 22,536 t harvested in 2019, when the state of Rio Grande do Sul (10,254 t) was the largest producer followed by the state of São Paulo (9,017 t) (IBGE, 2021).

The better part of the production of figs is sent for processing. However, in recent years, the demand for *in natura* fruit has been increasing and there is a prospect for further increase, in particular when produced under agricultural models that preserve the quality of the product and guarantee food security (Souza *et al.*, 2018).

Soil fertility management is one of the most important practices and with a direct link to the crop's productive success. The use of alternative fertilizers of natural source or organic instead of chemical ones, may come up as an interesting and promising option since, in addition to providing nutrients, it can improve soil conditions by increasing retention of water and nutrients (Caetano & Carvalho, 2006; Silva *et al.*, 2018; Lopes *et al.*, 2020).

Bird (BM) and cattle manure (CM) stand out among the most widely used organic fertilization sources, whether for their characteristics or for the higher offering of

these waste products in rural areas. Fertilization using CM is highly recommended in fig tree plantations with this form of fertilization promoting benefits such as improvement of soil physical properties, delivery of nutrients and increased population of nematophages organisms (Caetano & Carvalho, 2006; Wille *et al.*, 2018; Lopes *et al.*, 2020; Silva *et al.*, 2020). Authors consider that BM has N rich compounds and high levels of P and K and that, when applied on soils, contributes to reducing phytopathogens in this environment (Blum *et al.*, 2003).

Despite there being an understanding of the benefits of organic fertilization on crops, there is a material dearth of technical and scientific information on the use of organic fertilizer sources as substitutes for chemical fertilizers in agroecological models of fig plantations. The lack of information is even greater when looking for knowledge on alternative organic fertilization sources for this crop, other than CM, the most commonly used, in this case BM also stands out.

This paper's objective was to evaluate the effect of organic fertilization using manure in the production of ripe figs in ecologically friendly farming systems.

Material and methods

The experiment was carried out in the Orchard of the Canguiri Experimental Farm, located in the municipality of Pinhais-PR, belonging to the Agrarian Sciences Sector of the Federal University of Paraná-UFPR, Curitiba, Paraná State, Brazil, at 25° 25' latitude S and 49° 08' longitude W and altitude between 915 and 930 m.

The fig orchard was established in August 2011 by planting 'Roxo de Valinhos' cultivar cuttings with length of 40 cm planted in pits. Pit spacing was of 1.0 m in the row and 2.5 m between rows. All pits received baseline fertilization by applying 108 g of P in the 0-20 cm layer and 215 g in the 20-40 cm layer, using natural Gafsa phosphate.

In 2011, prior to the introduction of the fig orchard, soil samples were taken at the depths (layers) of 0-0.2 m and 0.2-0.4 m for chemical and physical analysis purposes in order to determine the soil properties, as follows in Table 1.

At 90 days after planting, only one fig plant with the strongest sprouting and best developed was left in each pit, the others were removed. The fig plants were then maintained as single shaft until the following winter when, in early August 2012, the first pruning was performed to open the 4 streams in which only two sprouts were maintained, thus resulting in a productive tree top of 8 productive branches. From year 2, the annual production pruning (winter) was always performed in the first week of August in order to preserve 10 cm of the branch, produced in the preceding season.

The fig orchard management was based on agricultural-ecological practices. Among these, weed control through manual and hoeing in between rows, mulch (straw) applied under the tree top, inter-crop with black oats (*Avena strigosa*) during the winter. Phytosanitary control was based on a winter treatment with sulfur-calcium liquid mixture at 0.1% and during the vegetative and productive periods. Bordeaux mixture at 0.2% was sprayed monthly during dryer periods and every two weeks on rainier periods. Bordeaux paste was applied using brushes on the trunk and open sections of the pruned branches. Pruning waste and infested shoots were removed and burned. Neem oil at 0.5% was applied to control pests.

The experimental plan applied was of random blocks with three repetitions per treatment and four plants per lot, with the two central ones being analyzed. Seven treatments were applied using two organic sources (CM and BM, both supplied by the organic system of animal production), with the control not receiving any fertilization. Treatments per plant were: T0) no fertilization (control), T1) 50% CM (5 L), T2) 50% BM (1.25 L), T3) 100% CM (10 L), T4) 100% BM (2.5 L), T5) 50% BM (1.25 L) + 50% CM (5 L), T6) 100% BM (2.5 L) + 100% CM (10 L). The standard manure dose applied used was 10 L of CM (100%) and 2.5 L of BM (100%). Fertilizer applications were performed annually in four stages: the first one always after winter pruning and the others at consecutive intervals of 60 days with fertilizer being applied on the planted row covering a radius of 0.5 m of the plant hub.

The pomological characteristics (number of fruits per plant, total fruit weight (FW) per plant (g), mean individual FW (g), mean fruit length and diameter (mm) were evaluated. Fruits were harvested three times a week from the beginning to the end of the harvesting period during two seasons: from January to March in 2016 and 2017.

Table 1. Descriptive analysis of the soil chemical properties at depth of 0-0.2 and 0.2-0.4 m cultivated with 'Brown Turkey' fig trees in the county of Pinhais, Paraná State, Brazil.

Soil layer (cm)	pH ($CaCl_2$)	P (mg dm^{-3})	C (g dm^{-3})	K^+	Ca^{2+}	Mg^{2+}	Al^{3+}	$H^+ + Al^{3+}$	SB	CEC	SBS (%)
				($cmol_c$ dm^{-3})							
0-20	6.2	23.6	24.3	0.68	8.1	4.4	0.0	2.7	13.2	15.9	83
20-40	6.2	7.3	22.2	0.46	8.1	4.3	0.0	2.7	12.9	15.6	83

SB: sum of bases. CEC: cation exchange capacity at pH 7.0. SBS: soil base saturation.

In the second year of the experiment, fruits were harvested weekly and taken to the post-harvest laboratory located at the Canguiri Experimental Farm to determine the quality characteristics. Five normal standard fruits were harvested per plant: ten fruits per repetition at the ripening point (more than 60% of the purple epidermis). The fruits were ground and the following characteristics were analyzed using the juice: total soluble solids (TSS) content was measured by the Tecnal pH Meter TEC-2 refractometer and expressed in °Brix; total titratable acidity (TTA) was determined in 10 mL of juice diluted in 90 mL of water, using 0.1 M NaOH solution under constant stirring, to pH 8.2, and expressed as percentage of citric acid; maturation index (MI) is expressed as TSS/TTA. Data were statistically analyzed applying ANOVA and comparison of means by Tukey test at 5% probability.

Results and discussion

Organic fertilizers and growing season influenced all characteristics evaluated (Table 2), but there was non-significant effect of interaction between both factors (organic fertilizer × season), which was expected due to the variation from one year to another to occur evenly, affecting the parameters being evaluated.

Table 2 shows that fig trees receiving CM alone (at 5 L or 10 L per plant) or combined with BM (5 L CM + 1.25 L BM) exhibited better results as compared to unfertilized trees for number of figs per plant (NFP) and total fruit weight per plant (FWP). The estimated yield for these treatments was 2,236.8 (T1); 2,271.2 (T3) and 2,265.2 (T5) t ha^{-1} yr^{-1}. Except for fertilization with T6 (10 L CM + 2.5 L BM), the highest yields were observed in fig trees that received CM fertilization in comparison with unfertilized fig trees. This result may be attributed to the fact that this organic fertilizer promoted improvements in soil conditions, especially regarding the additional nutrient supply (Caetano & Carvalho, 2006; Silva *et al.*, 2020).

For fig FW, doses of 50% (T1) or 100% CM (T3) and 100% CM + 100% BM (T6) featured better results than unfertilized fig trees (Table 2). Even so, there was an indication of an increase in the FW for fig trees fertilized with manure as compared to the unfertilized ones. For fig length (FL), only those that received 50% BM (T2) and 100% CM + 100% BM (T6) presented longer figs as compared to those that did not receive any fertilization. On the other hand, only trees fertilized with 50% CM + 50% BM (T5) or with 100% BM (T4) produced figs smaller than those of unfertilized fig trees.

Table 2 also shows that only the control and fertilization with 100% BM (T4) presented average diameter (DF) corresponding to unmarketable figs. The treatments with 100% CM (T3) and 50% CM (5 L) + 50% BM (1.25 L) (T5) produced figs classified as very small. The other fertilization options promoted the production of small figs. In Brazil, 'Brown Turkey' fig is considered unmarketable when diameter is <40 mm, very small size when its diameter is 40-45 mm, and small size when diameter is 45-50 mm (Programa Brasileiro para a Modernização da Horticultura, 2006).

It is important to stress that only the 50% CM treatment promoted superior results in all characteristics evaluated as compared to unfertilized fig trees (Table 2). The application and distribution of CM in the fig orchard may promote several benefits to the productive system: better plant nutrition, improved soil fertility, further development and growth of plants. Leonel & Damatto Júnior (2007) concluded that the application of manure to the soil improved the distribution of the fig tree roots and that the distribution of the root system was better in the horizontal direction.

Table 2. Average number of fruits per plant (NFP), total fruit weight per plant (FWP), average individual fruit weight (FW), length (FL) and diameter (DF) of figs harvested from fig fertilizing trials.

Treatment	NFP	FWP (g)	FW (g)	FL (mm)	DF (mm)
T0: Control	1.6 b	58.6 b	25.4 b	24.2 b	17.0 b
T1: 50% CM (5L)	11.2 a	559.2 a	49.2 a	62.3 a	47.0 a
T2: 50% BM (1.25L)	5.2 ab	217.9 ab	39.5 ab	58.9 ab	45.3 a
T3: 100% CM (10L)	11.3 a	567.8 a	49.9 a	57.6 ab	42.7 a
T4: 100% BM (2.5L)	8.7 ab	415.6 ab	37.8 ab	50.1 ab	38.4 ab
T5: 50% CM (5L)+50% BM (1.25L)	11.6 a	566.3 a	40.2 ab	52.0 ab	40.0 ab
T6: 100% CM (10L)+100% BM (2.5L)	10.5 ab	530.9 ab	54.6 a	64.0 a	49.4 a
Season					
2016	5.7 b	300.6 b	40.1 a	50.0 a	38.2 a
2017	11.5 a	532.7 a	44.6 a	55.6 a	41.8 a

CM: cattle manure. BM: bird manure. Means followed by different letters in the column, differ from each other at 5% de probability.

Comparing the two seasons, 2017 had the highest number of figs per plant and the highest yield per plant (Table 2). Two factors were most likely to be the determining factors in obtaining these results. First, the fact that the fig trees are still growing, as both harvests were performed when the plants were completing their fifth and sixth post-planting years, respectively. According to Silva (2009), 7-year-old fig trees are still considered young plants. Second, is the fact that fertilization over the years promote continuous improvement in soil, especially the amount of mineral elements available in the soil (Silva *et al.*, 2016; Seferoğlu *et al.*, 2017). Lopes *et al.* (2020) reported that CM at a concentration of 60% increased the leaf contents of N, P and K and reduced the levels of Ca and Mg in plants. Other authors observed that successive fertilization with CM increased the P and K levels in the soil and decreased the Al content, which may have been related to the increase in fig productivity (Caetano & Carvalho, 2006). Leonel & Tecchio (2009) pointed that besides N, CM provides other mineral elements such as P, K, Ca, Mg, Cu, Fe, Mn and Zn essential for plant development.

Although evaluated biometric characteristics of figs have shown trend to be better when highest organic fertilizer were applied in comparison with control, organic fertilizer must be applied with caution throughout the crop cycles in order to avoid overdoses and negative effects (Chen *et al.*, 2018). It may be the reason why the higher organic dose did not show better number of figs and fig weight than the control treatment.

There was no significant season effects on fruit weight, length and diameter, most likely because these characteristics were less affected by plant age.

Among the chemical characteristics that drive fruit quality, the only one not affected by organic fertilizers was the TSS content (Table 3). The fruits presented average values of TSS of 8.32 °Brix. The quality of the fruit depends on the amount and type of compounds that accumulate. Since fruits are storage organs, their composition depends on the adequate supply of carbon and nitrogen assimilation products (sugars and amino acids) (Nestby *et al.*, 2005). The different doses of manure supplied to the plants did not cause changes in the accumulation of TSS in the fruits. However, pH and TTA were affected by organic fertilization (Table 3). The lowest TTA values were obtained with 100% fertilization with CM or BM (T3 and T4).

MI was also influenced by organic fertilization with CM and BM (Table 3). MI promotes a better perception of the fruit flavor and plants fertilized with 2.5 L of BM (T4) produced figs with better MI (23.26) in comparison with fig trees fertilized with 5L of CM (17.70) or 1.25L of BM (17.98). On the other hand, no treatment showed better MI outcome against control.

For the production of ripe figs and considering the experimental conditions of this paper, organic fertilization with 5 L of cattle manure per fig tree applied four times annually can be recommended. As this fertilization promotes better results in number and mass of figs per plant, as well as better average mass, length and diameter of figs as compared to unfertilized plants, at the same time its dose is the lowest tested here what can result in less cost for the crop management. Considering quality, in its turn, the fertilization of 10 L of cattle manure or 2.5 L of bird manure provide lower total titratable acidity contents against ripe figs collected from unfertilized plants.

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Table 3. Total soluble solids content (TSS), pH, total titratable acidity (TTA) and maturation index (MI) of fruit harvested during 2017 in fig orchards fertilized with organic sources.

Treatment	TSS	pH	TTA	MI
T0: Control	8.19 a	4.76 b	0.48 a	18.08 abc
T1: 50% CM (5L)	8.60 a	4.76 b	0.48 a	17.70 c
T2: 50% BM (1.25L)	8.33 a	4.74 b	0.46 ab	17.98 bc
T3: 100% CM (10L)	7.85 a	4.82 ab	0.35 c	22.47 abc
T4: 100% BM (2.5L)	8.19 a	4.86 ab	0.36 c	23.26 a
T5: 50% CM (5L)+50% BM (1.25L)	8.37 a	4.95 a	0.38 bc	22.64 abc
T6: 100% CM (10L)+100% BM (2.5L)	8.76 a	4.88 ab	0.38 bc	23.14 ab

CM: cattle manure. BM: bird manure. TSS expressed in °Brix; TTA expressed in % citric acid. Means followed by letters in the column, differ from each other at 5% de probability.

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