Yield and morphological attributes of bell pepper fruits under biological fertilizers and application times[1]

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ABSTRACT

Bell pepper (*Capsicum annuum*) is one of the most consumed vegetables around the world. Balanced fertilization is essential for growing this vegetable. The objective of this study was to evaluate the yield and morphological attributes of bell pepper under doses and times of application of biological fertilizers. Two experiments were carried out with applications of biological fertilizers prepared from manure and enriched organic compounds with cattle manure and sheep manure. The experimental design was a randomized complete block design, in a 4 x 3 + 1 factorial scheme, with three replications, referring to doses of biological fertilizers (100, 200, 300 and 400 L ha^{-1}), times of application (0, 30 and 60 days after transplanting – DAT) and control. The evaluated variables were: total fruit weight (TFW), number of commercial fruits (NCF), number of non-commercial fruits (NNCF), fruit weight (FW), fruit diameter (FD), fruit length (FL), resistance of fruit peel (RFP), number of flower buds (NFB) and productivity (P). Biological fertilizers caused positive effects on TFW, NCF, FW and P of bell pepper. The application of cattle manure at 60 DAT and sheep manure at 30 DAT promoted a larger fruit diameter. The FW, FL and RFP were influenced by the doses and times of application of biological fertilizers. The application of biofertilizers is efficient in the production of bell pepper.

Keywords: biometry; *Capsicum annuum*; organic fertilizer; plant nutrition; productivity

INTRODUCTION

The fruits of bell pepper (*Capsicum annuum* L.) have a great diversity of shapes and flavors, being found in green, red, yellow, orange or purple, depending on the variety and maturity stage. They are widely used in the cooking of various regions of Brazil, being consumed unripe or ripe, however, the consumption of green fruits is predominant (Santos *et al*., 2013).

Changes in society's eating habits and concern for the environment are frequent, increasing the demands of the consumer market regarding the commercialization of foods that use less and less synthetic products in their production, making producers look for alternatives to meet this growing demand (Santos *et al*., 2018).

Intensive food production is usually accompanied by technology packages involving synthetic fertilizers and other agrochemicals to provide rapid and efficient responses to increased production. Linked to these inputs are the harms caused to the soil and plants, causing stress of crops and chemical overload of these environments, providing fall in productivity or even making it impossible to cultivate due to desertification, depending on the degree of severity (Bertollo *et al*., 2015).

Considering the increasing demand for food, the environmental problems facing society, the need for nutrient supply to the plants and the production costs, it is necessary to develop research in the agricultural sector that develops efficient alternatives that promote a common good among these factors, creating new perspectives of production (Chiconato *et al*., 2013).

The use of biological fertilizers or biofertilizers prepared with animal waste and other sources of nutrients and

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microorganisms has been a promising alternative, improving the chemical, physical and biological characteristics of the soil, promoting higher crop yields, and reducing costs with mineral fertilizers (Guimarães *et al*., 2017).

Mineral fertilizers can be replaced by biofertilizers to meet the nutritional requirements of plants, promoting maximum growth and productivity; however, it is necessary to establish adequate doses (Celedonio *et al*., 2016). Thus, the present study aimed to evaluate the morphological attributes and yield of bell pepper under doses and times of application of biological fertilizers.

MATERIALS AND METHODS

Description of the study site

Two experiments were conducted simultaneously in a commercial cultivation area in the Perímetro Irrigado Apolônio Sales (Apolônio Sales Irrigated Perimeter), Petrolândia, Pernambuco. Located in Pernambuco Semi-arid, on the banks of the São Francisco River. The climate according to the Köppen and Geiger classification is BSh type, characterized as warm semiarid (Parahyba *et al.*, 2004; Alvares *et al.*, 2014). A digital thermohygrometer and a pluviometer were installed to obtain daily data on temperature, relative humidity and rainfall (Figure 1).

Experimental design

Two biofertilizers were prepared, one biofertilizer with cattle manure and another biofertilizer with sheep manure. The experimental design was a randomized complete block in a factorial scheme (4 x 3 + 1), with three replications. The treatments were doses of biological fertilizers (100, 200, 300 and 400 L ha^{-1}), application times (0, 30 and 60 days after transplantation – DAT) and a control treatment (without application of biofertilizer).

As for application times, in treatments 1 to 4 the doses of biological fertilizers were applied in full on the day of transplantation (0 DAT). In treatments of 5 to 8 the doses were fractionated twice, at 0 and 30 DAT, and in the 9-12 treatments the doses were fractionated three times, with applications at 0, 30 and 60 DAT (Table 2).

Plant material

Seeds of peppers Solário hybrid was used. The seedlings were produced in 128-cell trays using commercial substrate. After 32 days after sowing, transplantation was performed with 1.5 x 0.5 m spacing. 80 kg ha^{-1} of urea was applied at five DAT, 130 kg ha^{-1} of NPK (06-24-12) was applied at seven DAT and 260 kg ha^{-1} of NPK (20-10-20) was applied at 37 DAT, as recommended for culture in the State of Pernambuco. The experimental plot consisted of four rows of four meters, corresponding to an area of 24 m^2, with 32 plants. The usable area was 6 m^2, consisting of the two central rows, eliminating two plants from the ends of each row, totaling 8 plants.

Soil and Biofertilizers

The soil was classified as an Oxisolic Quartzarenic Neossol (Santos *et al*., 2006). Even being installed parallel experiments a soil sample was collected from each area. The soil analysis of cattle manure was: pH (H_2O, 1:2.5) = 6.95; P (mg dm^{-3}) = 388.01; K^+ (mg dm^{-3}) = 152.88; Na^+ (cmol$_c$ dm^{-3}) = 0.12; H^++Al^{+3} (cmol$_c$ dm^{-3}) = 3.47; Al^{+3} (cmol$_c$ dm^{-3}) = 0.0; Ca^{+2} (cmol$_c$ dm^{-3}) = 3.50; Mg^{+2} (cmol$_c$ dm^{-3}) = 1.50; sum of bases (cmol$_c$ dm^{-3}) = 5.51; cation exchange capacity (cmol$_c$ dm^{-3}) = 8.98; base saturation (%) = 61.40; aluminium saturation (%) = 0.0; organic matter (g kg^{-1}) = 10.73; total organic carbon (g kg^{-1}) = 8.60. The soil analysis of sheep manure was: pH (H_2O, 1:2.5) = 6.81; P (mg dm^{-3}) = 497.50; K^+ (mg dm^{-3}) = 155.22; Na^+ (cmol$_c$ dm^{-3}) = 0.10; H^++Al^{+3} (cmol$_c$ dm^{-3}) = 3.14; Al^{+3} (cmol$_c$ dm^{-3}) = 0.0; Ca^{+2} (cmol$_c$ dm^{-3}) = 3.50; Mg^{+2} (cmol$_c$ dm^{-3}) = 1.50; sum of bases (cmol$_c$ dm^{-3}) = 5.10; cation exchange capacity (cmol$_c$ dm^{-3}) = 8.23; base saturation (%) = 61.92; aluminium saturation (%) = 0.0; organic matter (g kg^{-1}) = 14.83; total organic carbon (g kg^{-1}) = 6.23.

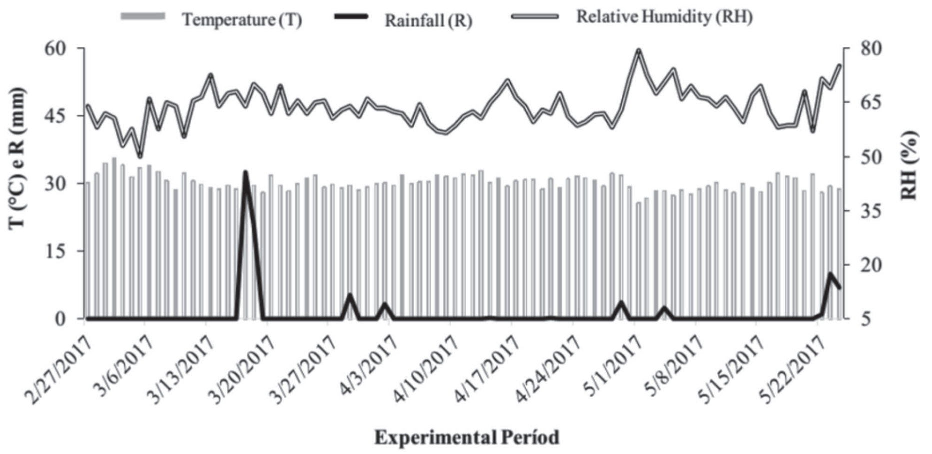

Figure 1: Temperature (T), rainfall (R) and relative humidity (RH) of bell pepper area in the experimental period.

The biological fertilizers were prepared according to the manufacturer's recommendations, using two biofactories (polyethylene water tanks) with a capacity of 100 liters. The biological fertilizers consisted of recalcitrant substances, biodynamic preparations, pentoses, minerals and bran (Microgeo, 2019).

Each biofactory was filled with five kilograms of enriched organic compound, 15 liters of manure (cattle or sheep) and 80 liters of water. Every three days the biological fertilizer was stirred and ready for use after 15 days of preparation (Microgeo, 2019). The application of biological fertilizers was performed on the soil surface, using a hand sprayer with a capacity of five liters, and the organic input was pre-filtered through a 2 mm mesh sieve.

Chemical analysis of biological fertilizers was performed. The analysis of cattle manure biofertilizer was: humidity (%) = 98.70; organic carbon (%) = 10.40; N (g L^{-1}) = 0.10; P (g L^{-1}) = 0.08; K^+ (g L^{-1}) = 30.90; Ca^{2+} (g L^{-1}) = 0.22; Mg^{2+} (g L^{-1}) = 0.58; S (g L^{-1}) = 0.05; Na (g L^{-1}) = 0.00; Cu (mg L^{-1}) = 0.43; Zn (mg L^{-1}) = 0.61; Fe^{3+} (mg L^{-1}) = 5.12; Mn^{2+} (mg L^{-1}) = 0.62; B (mg L^{-1}) = 2.22. The analysis of sheep manure biofertilizer was: humidity (%) = 98.80; organic carbon (%) = 11.10; N (g L^{-1}) = 0.11; P (g L^{-1}) = 0.07; K^+ (g L^{-1}) = 24.30; Ca^{2+} (g L^{-1}) = 0.15; Mg^{2+} (g L^{-1}) = 0.27; S (g L^{-1}) = 0.07; Na (g L^{-1}) = 0.00; Cu (mg L^{-1}) = 0.46; Zn (mg L^{-1}) = 0.54; Fe^{3+} (mg L^{-1}) = 10.60; Mn^{2+} (mg L^{-1}) = 0.51; B (mg L^{-1}) = 2.13.

Irrigation was performed by drip. The water came from the São Francisco River and the average daily-applied leaf was 9.12 mm per plant, split into two 4.56 mm applications, in the early morning and late afternoon. On days when there was sufficient rain, irrigation was suspended, supplementing when needed. Water analysis

Table 1. Summary of variance analysis of the variables evaluated in the first five bell pepper harvests under biological fertilizers, doses and application times

SV	TFW	NCF	AFW	FD	FL	FPR	NNCF	NFB	P
	P value								
Times (T)	0.1679^{ns}	0.2305^{ns}	0.4097^{ns}	0.0719^{ns}	0.3779^{ns}	0.5499^{ns}	0.7348^{ns}	0.8656^{ns}	0.5383^{ns}
Dose (D)	0.3913^{ns}	0.2568^{ns}	0.0902^{ns}	0.028^{ns}	0.4976^{ns}	0.6256^{ns}	0.4755^{ns}	0.6609^{ns}	0.6071^{ns}
Fertilizer (F)	0.0097**	0.0374*	0.0047**	0.365^{ns}	0.5495^{ns}	0.4342^{ns}	0.4893^{ns}	0.0897^{ns}	0.0114*
T x D	0.9778^{ns}	0.8123^{ns}	0.0504^{ns}	0.025*	0.2639^{ns}	0.4715^{ns}	0.0533^{ns}	0.3663^{ns}	0.8057^{ns}
T x F	0.5241^{ns}	0.7532^{ns}	0.0555^{ns}	0.0022**	0.5063^{ns}	0.6575^{ns}	0.0378*	0.6401^{ns}	0.7283^{ns}
D x F	0.8262^{ns}	0.7246^{ns}	0.8847^{ns}	0.7099^{ns}	0.7544^{ns}	0.6291^{ns}	0.646^{ns}	0.9832^{ns}	0.7629^{ns}
TxDxF	0.6331^{ns}	0.8278^{ns}	0.1746^{ns}	0.1607^{ns}	0.2589^{ns}	0.3552^{ns}	0.3404^{ns}	0.6421^{ns}	0.1591^{ns}
CV (%)	0.32	36.15	2.03	3.25	4.14	76.65	23.28	9.90	12.11
CM	715.86 b	7.38 b	96.49 b	#	-	-	#	-	18.87 b
SM	828.03 a	8.27 a	100.09 a	#	-	-	#	-	21.58 a

CV: coefficient of variation; SV: source of variation; P value: probability of difference between treatments and interactions; **, * significant at the 1 and 5% probability level (p<0.01 and p<0.05), respectively; ns: not significant. # Treatment with significative interaction. CM and SM: cattle and sheep biological fertilizer, respectively. Means followed by the same letter in the column do not differ by F test.

Table 2: Details of treatments as to the times and doses of application of biological fertilizers

Treatments	Application Times (DAT)	0	30	60
		Doses (L ha^{-1})		
1	0	100.00		
2	0	200.00		
3	0	300.00		
4	0	400.00		
5	30	50.00	50.00	
6	30	100.00	100.00	
7	30	150.00	150.00	
8	30	200.00	200.00	
9	60	33.33	33.33	33.33
10	60	66.66	66.66	66.66
11	60	100.00	100.00	100.00
12	60	133.33	133.33	133.33
13	Control	0.00	0.00	0.00

DAT = days after transplantation

was performed: pH = 6.7; electrical conductivity (dS m^{-1}) = 0.069; SO_4^{-2} (mg L^{-1}) = 0.00; Mg^{+2} ($mmol_c$ L^{-1}) = 0.18; Na^+ ($mmol_c$ L^{-1}) = 0.20; K^+ ($mmol_c$ L^{-1}) = 0.10; Ca^{+2} ($mmol_c$ L^{-1}) = 0.10; CO_3^{-2} ($mmol_c$ L^{-1}) = 0.00; HCO_3^{-2} ($mmol_c$ L^{-1}) = 1.20; Cl ($mmol_c$ L^{-1}) = 0.30; sodium adsorption ratio ($mmol_c$ L^{-1}) = 0.60; exchangeable sodium percentage ($mmol_c$ L^{-1}) = 0.00; classification = C_1S_1 (Richards, 1954).

Measured variables

The total fruit weight per plant (TFW – expressed in g), weighing all fruits harvested on the plant, using a digital scale, was evaluated. The number of commercial fruits per plant (NCF) was evaluated counting the number of fruits harvested per plant. The number of non-commercial fruits per plant (NNCF) was evaluated counting in the fruits that were not yet present at the point of harvest. The average fruit weight per plant (AFW – expressed in g) was evaluated dividing the TFW by the NCF. The fruit diameter (FD – expressed in mm) was evaluated by measuring the with the aid of a digital caliper. The fruit length (FL – expressed in cm) was evaluated measuring the longest fruit length. The fruit peel resistance (FPR) was evaluated using an analogic penetrometer (model GY-3, Luzeren®). The number of flower buds (NFB) was evaluated counting the number of flowers per plant. The productivity (P – expressed in t ha^{-1}) was evaluated estimating the yield per hectare using the total fruit weight per plant. In order to obtain the values of each variable mentioned above, the data averages of five harvests performed at 59, 66, 73, 80 and 87 DAT were calculated.

Statistical analysis

Data averages for the first five harvests were subjected to the normality (Shapiro-Wilk) and homogeneity (Bartlett) tests and then subjected to analysis of variance. When significant differences by the F test, the average test was performed (Tukey test up to 5% probability) for qualitative factors (biological fertilizers) and regression analysis for quantitative one (doses and application times). To compare factor combinations with additional treatment, the Dunnet test at 5% probability was performed. The statistical program used was R (R Core Team, 2018) and ExpDes (Ferreira *et al*., 2018) and multcomp (Hothorn *et al.*, 2008) packages.

RESULTS AND DISCUSSION

Differences were observed between the biological fertilizers for total fruit weight per plant (TFW), number of commercial fruit per plant (NCF), average fruit weight (AFW) and productivity (P). Interactions were observed between application times and doses of biological fertilizers and between application times and biological fertilizers for fruit diameter (FD). The number of non-commercial fruits per plant (NNCF) had interaction between application times and biological fertilizers. The average fruit length (FL), fruit peel resistance (FPR), the number of flower buds (NFB) did not differ among biological fertilizers, doses, and application times (Table 1).

Biological fertilizer with sheep manure provided better results for the TFW (828.03 g), NCF (8.27), AFW (100.09 g) and P (21.58 t ha^{-1}). This was due to biological fertilizer has caused greater benefits to the soil and to the decomposing microorganisms, promoting greater availability of nutrients to the plants and consequently higher productive performance.

The TFW was 13.55% higher in bell pepper plants fertilized with sheep manure. The TFW an NCF of four bell pepper cultivars grown in organic production system was 19.6 t ha-1 and 8.6 fruits, respectively (Negretti *et al*., 2010). It was 9.2% lower than the obtained in the sheep manure in this present study.

Bell pepper hybrids grown in conventional and organic cultivation systems had NCF and TFW of 3.29 and 331.56 g in the conventional system 3.0 and 367.24 g in the organic system, respectively (Pimenta *et al*., 2016). According these authors, the two systems evaluated had values below those observed in this study, demonstrating once again that the cultivation of peppers under biological fertilization has better results, probably by multiple benefits added to the soil and therefore the plants.

The AFW of bell pepper grown in the conventional cultivation system was 101.44 g and in organic system was 101.92 g (Pimenta *et al*., 2016), results close to that obtained in present study (100.00 g). It means that the AFW is similar in the management adopted in the cultivation of the bell pepper; however, the application of biological fertilizers provides greater fruit production, leading to the higher TFW and consequently the higher P.

The application of swine manure biofertilizer in two bell pepper cultivars increased the yield for Rubia cultivar (21.45 t ha^{-1}) and for Amanda cultivar (17.22 t ha^{-1}) (Sediyama *et al*., 2014). The average yield of this study was 21.58 t ha^{-1} for sheep manure, similar to that found in Rubia cultivar, and 18.87 t ha^{-1} for cattle manure. Despite the similarity between the values, the volume of biological fertilizers applied in this work (100 to 400 L ha^{-1}) is much lower than the one applied by the authors (120 m^3 ha^{-1}), which implies a lower need for labor and inputs, directly influencing the cost of production.

Application of liquid biofertilizers increased the fruit mass of aji pepper (Oliveira *et al*., 2014). This was due to nutritional properties, derived from the decomposition of organic matter, which stimulate the soil microbiological community, promoting greater nutrient availability for plants and improving soil physical characteristics, resulting in higher crop yield.

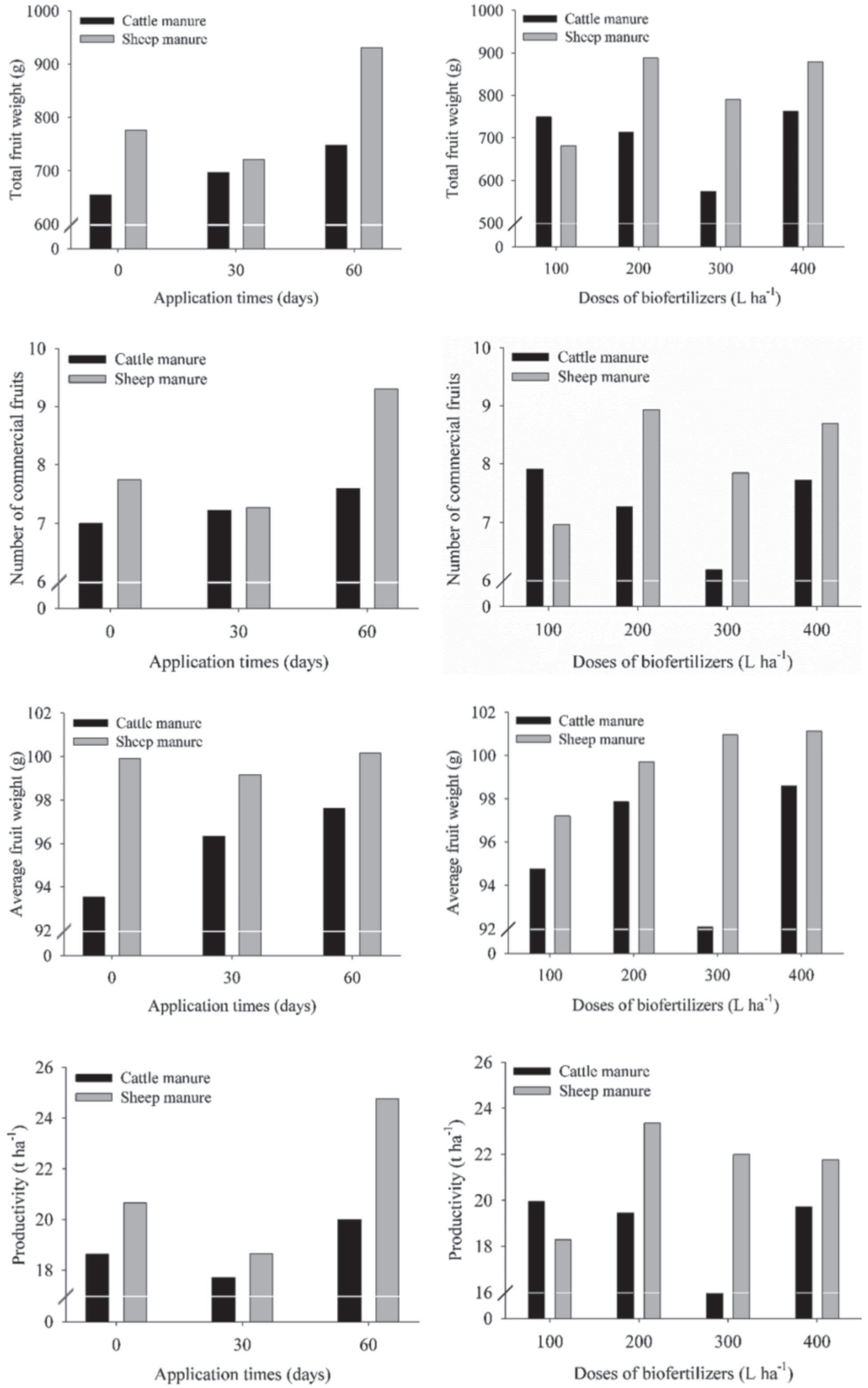

Figure 2: Total fruit weight, number of commercial fruits, average fruit weight and productivity of bell pepper fruits under biological fertilizers, doses and application times.

The productivity of pumpkin fruits increased with application of swine biofertilizer (Santos *et al*., 2012). The largest production passion fruit production under irrigation with saline water was observed in plants that have been fertilized with biofertilizer due to the higher biological activity in the soil and adequate nutrient availability from biological fertilizer (Dias *et al*., 2011).

Interactions were observed for fruit diameter between application times and doses of biological fertilizers and between application times and biological fertilizers (Figure 3A). The largest fruit diameter (7.64 cm) was observed in bell pepper plants fertilized with cattle manure at the time of application 60 days. Sheep manure was higher than cattle manure only at the time of application 30 days. There was a difference only for the application time 30 days in relation to the doses of biofertilizers (Figure 3B). Interactions were observed for number of non-commercial fruits, difference was observed only in the application time 0 days. The largest number of non-commercial fruits (14.28 fruits) was observed in plants fertilized with cattle manure (Figure 3C). This result is congruent, since the highest number of commercial fruit was obtained with sheep manure, variable that considers the fruits harvested. As for the time of application, it can be justified due to the greater distance in days between the application of biological fertilizers and the harvesting period, reducing their effectiveness in providing higher number of commercial fruit.

Interaction between doses and times of application of suine biofertilizer (Sediyama *et al*., 2014), as in the present study. The largest fruit diameter (6.28 cm) o and fruit length (15.05 cm) was observed in bell pepper (Lopes *et al*., 2018), stating that these are attributes of economic importance, as they are evaluated by consumers, influencing the attractiveness of the fruits, the choice and consequently the purchase of bell pepper.

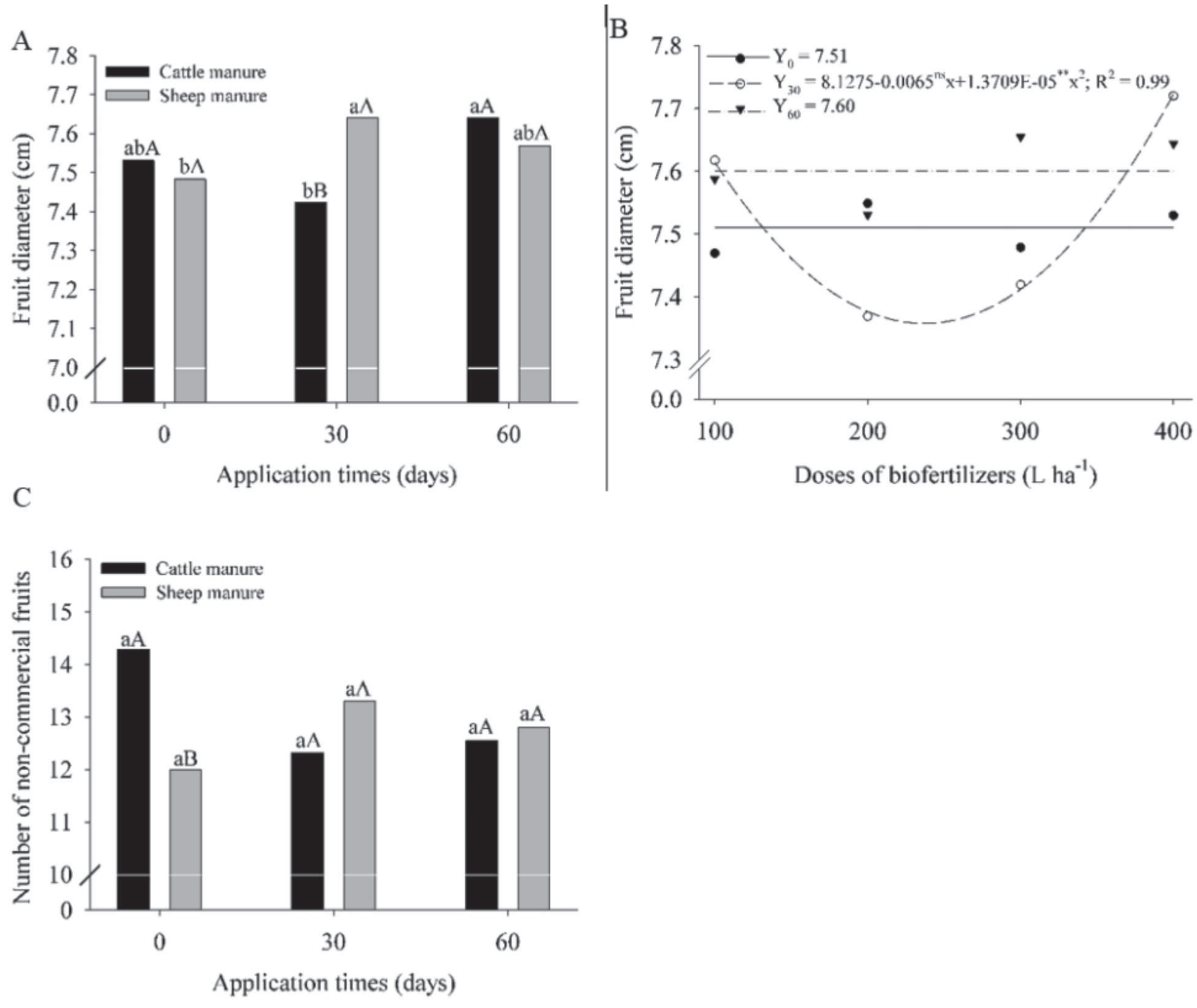

Figure 3: Interactions between application times and doses of biological fertilizers (A) and between application times and biological fertilizers (B) for stem diameter and interaction between application times and doses of biological fertilizers (C) for number of non-commercial fruits of bell pepper. Means followed by capital letters between biological fertilizers and lower case letters between application times do not differ by the Tukey test.

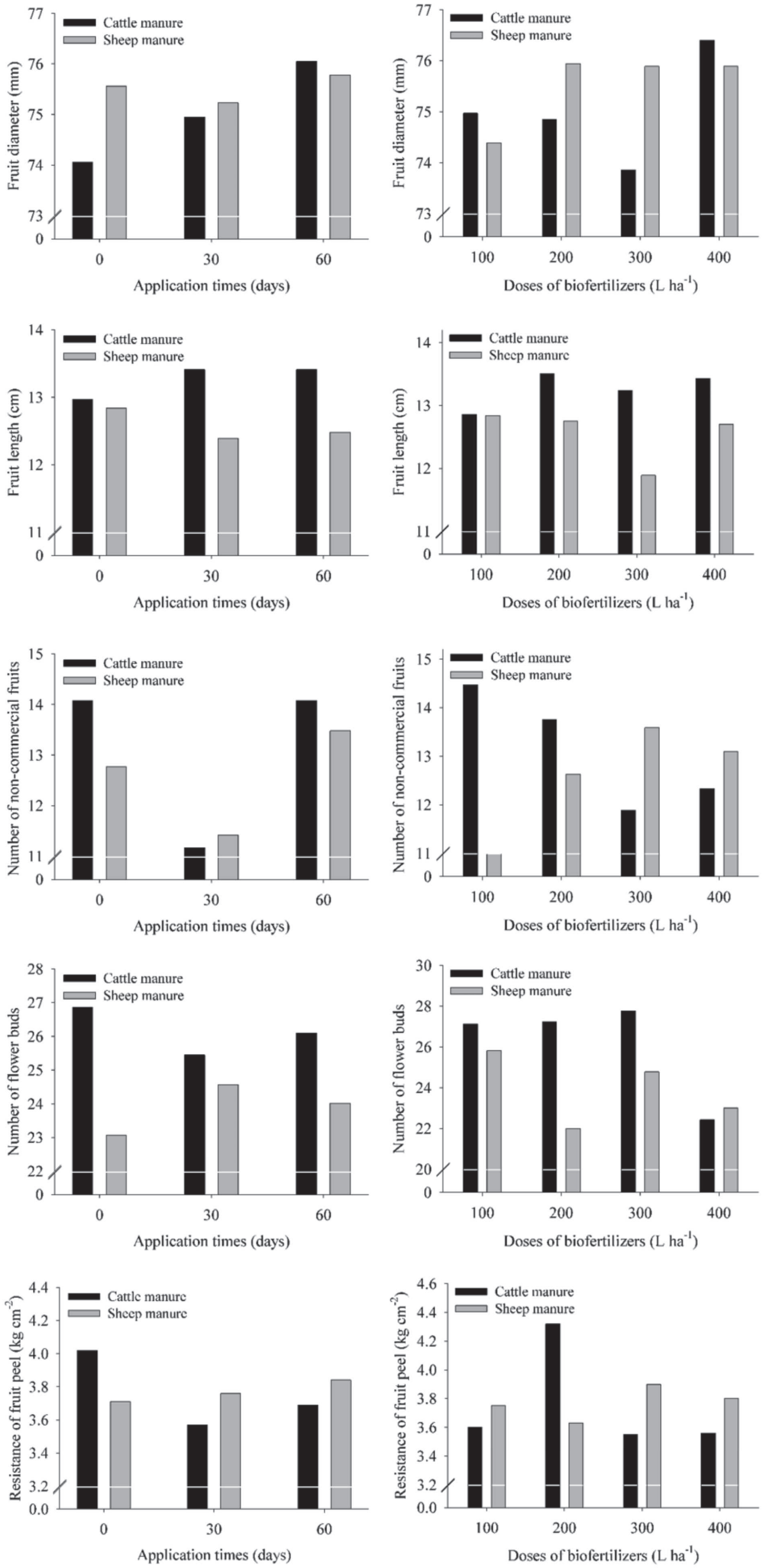

Figure 4: Fruit diameter, fruit length, number of non-commercial fruits, number of flower buds and fruit peel resistance of bell pepper under biological fertilizers, doses and application times.

The largest fruit diameter (7.51 cm) of Solario hybrid was observed in the conventional cultivation system compared to the organic cultivation system (7.79 cm), justified by the greater aptitude of the hybrid (Pimenta *et al.*, 2016). The average fruit diameter of three bell pepper cultivars grown under alternative substrates had of 6.4 cm at 74 DAT (Hachmann *et al.*, 2017), showing that the substrates did not increase fruit development.

The biological fertilizers, doses and times of application had no significant differences for fruit lenght, fruit peel resistance and number of flower buds (Figure 4), probably due to the variety used to present great uniformity for these attributes, keeping close the respective values of each plant. In organic cultivation system, the Solário hybrid bell pepper obtained fruit lenght of 7.86 cm and in conventional cultivation of 7.52 cm (Pimenta *et al.*, 2016). No effects found on fruit peel resistance and fruit length of bell pepper cultivated in organic system under fertilization with seaweed (Sá, 2014).

Comparing all treatments with the control by the Dunnett test at 5% probability, it was observed that the average fruit weight, fruit length and fruit peel resistance had a positive effect on applied biological fertilizers (Figure 5). No differences were observed for the other variables, so the graphs are not shown. For average fruit weight, the treatment 8 (30 days and dose 400 L ha^{-1}) of the sheep manure had greater results than the control. For fruit length and fruit peel resistance, the treatments 7 (30 days and 300 L ha^{-1} dose) and 11 (60 days and 300 L ha^{-1} dose) of cattle manure had the best results than the control.

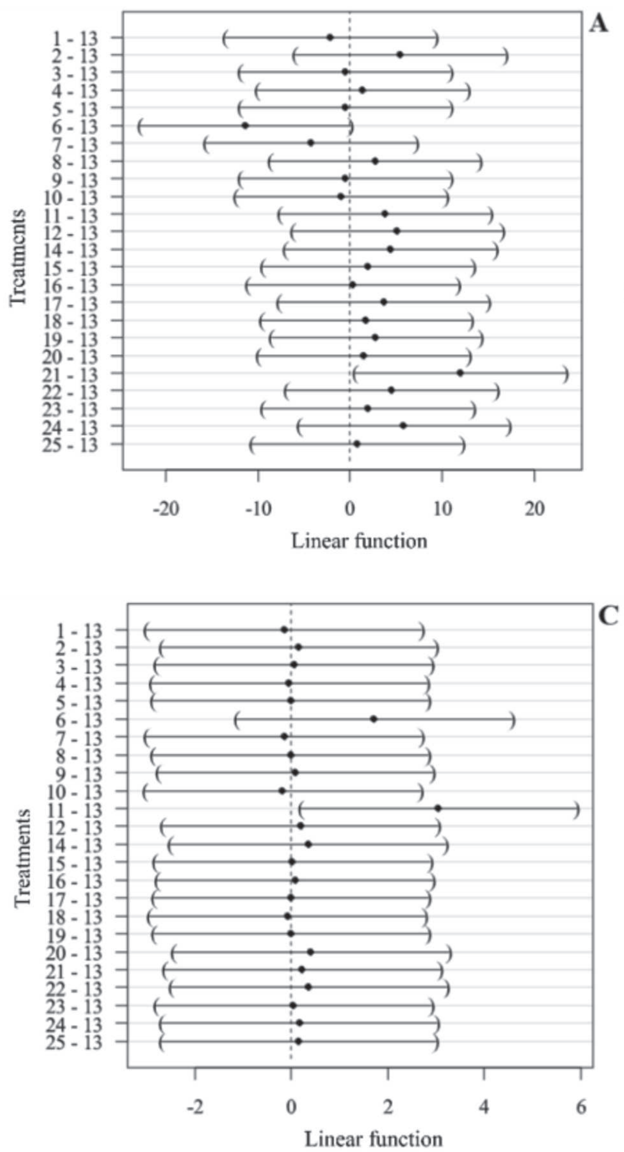

Figure 5: Dunnett test for average fruit weight (A), fruit length (B) and bell pepper peel resistance (C) under biological fertilizers, doses and application times. Treatments 1 to 12: referring to the experiment with cattle manure; treatments 14 and 25: referring to the sheep manure; 13: control.

CONCLUSIONS

Organic fertilizers have positive effects on total fruit weight, number of commercial fruits, average fruit weight and bell pepper yield. The 300 L ha^{-1} dose at 30 days after transplantation (DAT) promotes a significant increase in the diameter of bell pepper fruits. The application of cattle biological fertilizer at 60 DAT and the sheep biological fertilizer at 30 DAT promotes a larger diameter of bell pepper fruits. The average fruit weight, fruit length and fruit peel strength are influenced by the doses and application times of biological fertilizers. The application of biofertilizers is efficient in the production of bell pepper.

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