

# Physical characteristics of fruit of yellow passion fruit produced in soil with bio-fertilizer, mulching and saline water

## *Características físicas de los frutos del maracuyá amarillo producido en suelo con biofertilizante, mantillo y agua salina*

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### ABSTRACT

The size and yield of fruit are important in the physical quality of the fruits destined for markets and industry. An experiment was performed to evaluate the form, peel strength and yield of fruits of yellow passion fruit plant produced in substrata with bovine bio-fertilizer and mulching, irrigated with saline water. The treatments were designed in three random blocks using a 2 x 2 x 2 factorial arrangement; irrigation with non-saline (0.50 dS m<sup>-1</sup>) and saline (4.50 dS m<sup>-1</sup>) water, with and without application of bovine biofertilizer and with and without mulching. The passion fruit fruits were harvested when 30% of the peel was yellowish; we evaluated the diameter of the longitudinal cavity (length), diameter of the equatorial cavity (width), fruit form index, peel strength and juice and pulp yield. The substrate with bovine bio-fertilizer and mulching irrigated with high salinity water reduced the diameter of the longitudinal and equatorial cavity, the fruit form index and increased the firmness of the peel of the fruits of the yellow passion fruit plant. However, the use of the bovine biofertilizer and mulching irrigated with non-saline water increased the diameter of the equatorial and longitudinal cavity and the fruit form index.

**Key words:** *Passiflora edulis*, quality of fruit, salinity, organic input.

### RESUMEN

Las dimensiones y el rendimiento de los frutos son características fundamentales para la calidad de frutos destinados al mercado y la industria. En este sentido se realizó un experimento para evaluar el formato, resistencia y rendimiento de maracuyá amarillo producido en sustrato con biofertilizante bovino, mantillo e irrigado con agua salina. El diseño experimental fue de tres bloques al azar, con un arreglo factorial de 2 x 2 x 2, los factores evaluados fueron: agua de riego no salina (0,50 dS m<sup>-1</sup>), salina (4,50 dS m<sup>-1</sup>), con aplicación y sin aplicación de biofertilizante bovino, con y sin mantillo. Los frutos de maracuyá fueron cosechados con 30% de corteza amarillenta y se evaluó el diámetro de la cavidad longitudinal (largura), diámetro de la cavidad ecuatorial (transversal), índice de formato de los frutos, resistencia de la cáscara y rendimiento de jugo y pulpa. Los mayores valores de diámetro de la cavidad longitudinal, diámetro de la cavidad ecuatorial, índice de formato de los frutos y rendimiento de jugo y pulpa se obtuvieron con el uso de biofertilizante bovino y mantillo en los sustratos regados con agua de alto nivel de salinidad. El uso de agua de alto nivel de salinidad redujo el diámetro de la cavidad longitudinal, el diámetro de la cavidad ecuatorial, el índice de formato de los frutos, independientemente de la presencia de insumos orgánicos en el sustrato y aumentó el rendimiento de jugo, pulpa y resistencia de la cáscara en los tratamientos sin biofertilizante y sin mantillo. El mayor índice de formato del fruto presentó el mayor rendimiento de jugo.

**Palabras clave:** *Passiflora edulis* L., calidad del fruto, salinidad, insumos orgánicos.

### Introduction

Yellow passion fruit is native to tropical America; it is grown and processed in all countries of the world. In Brazil it is grown from north to south, with a total production of 614,000 t of fruit in an area of 45,300 ha

(Agriannual, 2009). The northeast region is the greatest producer (Vianna-Silva *et al.*, 2008); production is destined to the preparation of frozen juice concentrate and fresh consumption (Santos *et al.*, 2009).

One of the concerns of the producers of this fruit in the northeast region of Brazil is to produce quality

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fruit of passion fruit using the natural resources available in the region, which is fundamental to foment regional development and the generation of jobs and income in the field (Pimentel *et al.*, 2009). Most of the crops grown in the northeast region of the country suffer water stress during the growth and development of the plants. In the case of yellow passion fruit, water deficit during the production phase may lead to a decrease in fruit weight and pulp volume, wilt and finally fruit fall (Teixeira *et al.*, 1990), affecting productivity in mean weight, length and diameter of the fruit (Cavichioli *et al.*, 2008).

In addition to the water deficit, the northeast region must face salinity, usually due to the high evapotranspiration demand, reduced precipitation and poor management of drainage (Silva *et al.*, 2009). According to Ayers & Westcot (1999), yellow passion fruit is highly sensitive to the action of salts; irrigation with saline water may produce undesired effects in the physicochemical quality of the fruit (Costa *et al.*, 2001; Freire *et al.*, 2010; Dias *et al.*, 2011).

The fruit form index is important in classification and standardizing; it affects the acceptance and judgment of the product in some markets (Purquerio & Cecilio Filho, 2005). For fresh consumption, yellow passion fruit is classified by size (Meletti, 2001) and external aspect (Hafle *et al.*, 2009), given that consumers prefer oval fruits (Oliveira *et al.*, 2008) with an attractive aspect which are sweeter and less acid (Cavichioli *et al.*, 2008), as well as uniform color, resistance to transport and useful post-harvest life which satisfies market standards (Vianna-Silva *et al.*, 2008).

Recent research using organic products such as bovine bio-fertilizer and mulch in the soil has shown promising results, finding significant increases in yield in most crops irrigated with saline water (Campos *et al.*, 2007; Freire *et al.*, 2010; Freire *et al.*; 2011; Davis *et al.*, 2011; Campos *et al.*, 2011a; Campos *et al.*, 2011b). Thus the purpose of this study was to evaluate the physical attributes of yellow passion fruit irrigated with low and high salinity in substrate with bovine bio-fertilizer and mulch.

## Materials and Methods

The study was performed between September, 2009 and April, 2010, using pressure lysimeters installed in the experimental field of Remigio

(6° 53' 00" S, 36° 02' 00" W), in the agricultural area of the Estate of Paraiba, Brazil. The climate is warm and humid; during the study period precipitation was 166 mm and the mean air temperature oscillated from 25 °C to 28 °C.

Pressure lysimeters were constructed in plastic recipients with substrate capacity of 130 dm<sup>3</sup> (60 cm diameter x 50 cm height) installed with a separation of 3.0 x 3.0 m over a brick platform 30 cm above soil level. Two equidistant 1 cm diameter drainage holes were perforated in the internal base of each to collect drained solution. To avoid clogging of the holes a 2.5 cm layer of gravel was placed first, covered by a 5 cm layer of sand; the remainder was substrate. The substrate consisted of a mixture of soil removed from the top 10 cm of a eutrophic yellow ultisol (Santos *et al.*, 2006), with bovine feces (C/N ratio 16/1 and 12% humidity) in 10:1 volumetric proportion. The substrate was analyzed using the methodology proposed by Embrapa (2011), showing the following physical attributes: sand, silt, clay and clay dispersed in water = 28, 106.66 and 26 g kg<sup>-1</sup>; degree of flocculence and dispersion index = 60.6% and 39.9%; soil and particle densities 1.26 and 2.73 g cm<sup>-3</sup>; total porosity = 0.54 m<sup>3</sup> m<sup>-3</sup>; soil humidity at 0.033MPa, 0.1MPa, 1.0 MPa and 1.5 MPa = 103, 82.8, 55.4 and 30.7 g kg<sup>-1</sup>, respectively; Na<sup>+</sup>, Ca<sup>2+</sup>, Mg<sup>2+</sup>, H<sup>+</sup>+ Al<sup>3+</sup>, CIC<sub>pH7.0</sub> = 0.29, 3.95, 1.10, 1.65 and 7.30 cmolc dm<sup>-3</sup> respectively; base saturation = 77.4% and MO = 11.8 g kg<sup>-1</sup>.

Treatments consisted of two levels of electrical conductivity (EC) of irrigation water (non-saline EC = 0.50 dS m<sup>-1</sup> and saline water EC = 4.50 dS m<sup>-1</sup>), with and without application of bovine bio-fertilizer and with and without mulch in a 2 x 2 x 2 factorial arrangement, using three repetitions and three plants per experimental unit. The less saline water came from a superficial source in the experimental area; this was also used to dilute highly saline water (EC = 9.50 dS m<sup>-1</sup>) to obtain the experimental EC of 4.50 dS m<sup>-1</sup>. Plants were watered daily with 20% of the water layer evaporated during the previous day, measured in a class A tank installed beside the experimental zone.

The bovine bio-fertilizer was obtained by anaerobic fermentation of fresh cow feces mixed 1:1 with water without chlorine and left in a hermetically sealed container for at least 30 days (Santos & Akiba, 1996). The methane gas produced in the fermentation was liberated by means of a hose connected to the top of the biodigester; the other end

of the hose was submerged in water to impede air entrance. Each lysimeter received 10 dm<sup>3</sup> of bovine bio-fertilizer diluted 1:1 with water and applied to the surface of the substrate, one week before and every 90 days after transplanting until the end of the experiment, as suggested by Cavalcante *et al.*, (2007). The analytical measurements of the salinity of the diluted bovine bio-fertilizer and irrigation water using the methods of Richards (1954) and Embrapa (2011) are given in Table 1. Bermuda grass (*Cynodon dactylon* L.) was used for mulch after drying at environmental temperature; a 10 cm layer was placed on the substrate surface. Mulch was replaced every two months.

Plantlets of yellow passion fruit were produced in polyethylene bags (18 cm height, 13 cm diameter and transplanted to the pressure lysimeters in September, 2009. After careful study, plants 30 cm tall with 5 pairs of leaves were chosen. Before application of bovine bio-fertilizer and planting, the substrate in each lysimeter was fertilized with 150 g of simple superphosphate (20% P<sub>2</sub>O<sub>5</sub>).

Substrates were watered 21 days after transplant (DAT) to saturation with their treatment solutions. At 30 DAT 10 g of fertilizer (45% N) was applied in the top soil level; after this 30 g fertilizer (45% N) and 50 g potassium chloride (58% K<sub>2</sub>O) per plant was applied monthly. When flowering began, 50 g simple superphosphate per plant was applied.

Yellow passion fruit plants were trained in vertical trellises with smooth N° 12 galvanized wire at 2.30 m above the soil surface, tied and stretched to posts of black wood separated by 3 m. Plants were tied during growth with cord (or String) of sisal to guide the stems to the trellises;

ties were loose to avoid strangulation of the stems when they thicken. Tips were clipped when the stem main reached 10 cm above the high part of the trellis and also when the secondary branches reached 1.50 m length. Tips of tertiary branches were trimmed at 0.30 m above soil level to stimulate budding of lateral buds and produce buds oriented to both sides of the trellis. Once flowering began daily manual pollination was performed with pollen from other plants.

During production, nine fruits with at least 30% of the skin yellow were collected per treatment. The fruits were shipped in polyethylene trays for analysis of their physical attributes to the Laboratory of Biology and Postharvest Technology. Fruit characters evaluated were longitudinal diameter (LD) (cm) and equatorial diameter (ED) (cm), measured with a digital Vernier caliper; the results were used to calculate the diameters of the longitudinal (LDC) and equatorial (EDC) cavities (cm):

$$LDC = [(LD) - (CE * 2) / 10] \quad (1)$$

$$EDC = [(EC) - (EC * 2) / 10] \quad (2)$$

where LDC = longitudinal diameter of the fruit cavity (cm), EDC = equatorial diameter of the fruit cavity (cm) and EC is the thickness of the peel (mm).

The fruit form index (FFI) is a relation between the longitudinal and equatorial diameters of the fruit. The peel strength (PS) was measured with a Mc Cornick FT 327 ® penetrometer with 8 mm diameter tip; finally the pulp yield (PY) and juice yield (JY) were measured by the percentage relation between the pulp and juice mass and the fruit mass.

Table 1. Saline characteristics of the bovine bio-fertilizer and irrigation water.

Characteristic	Bio-fertilizer	Non-saline water	Saline water
pH	6.7	6.4	7.7
EC (dS m <sup>-1</sup> a 25° C)	2.55	0.50	4.50
RAS (mmol L <sup>-1</sup> )	0.87	2.12	0.57
Ca <sup>2+</sup> (mmol <sub>c</sub> L <sup>-1</sup> )	13.7	1.67	2.80
Mg <sup>2+</sup> (mmol <sub>c</sub> L <sup>-1</sup> )	17.5	0.81	8.90
K <sup>+</sup> (mmol <sub>c</sub> L <sup>-1</sup> )	3.33	0.11	0.43
Na <sup>+</sup> (mmol <sub>c</sub> L <sup>-1</sup> )	3.42	2.37	32.0
SO <sub>4</sub> <sup>2-</sup> (mmol <sub>c</sub> L <sup>-1</sup> )	20.9	0.86	0.26
CO <sub>3</sub> <sup>2-</sup> (mmol <sub>c</sub> L <sup>-1</sup> )	< UDL	< UDL	0.10
HCO <sub>3</sub> <sup>3-</sup> (mmol <sub>c</sub> L <sup>-1</sup> )	2.50	112	3.20
Cl <sup>-</sup> (mmol <sub>c</sub> L <sup>-1</sup> )	10.0	3.14	40.8
Classification	C <sub>4</sub> S <sub>1</sub>	C <sub>1</sub> S <sub>1</sub>	C <sub>4</sub> S <sub>1</sub>

EC - Electrical conductivity; RAS - Sodium absorption ratio [Na<sup>+</sup>/(Ca<sup>2+</sup>+Mg<sup>2+</sup>/2)<sup>1/2</sup>]; UDL - Under detection limit.

Results were interpreted by a factorial analysis of variance with Tukey *a posteriori* tests using an error rate of 5%, according to Banzatto & Kronka (2006).

## Results and Discussion

Fruits of the yellow passion fruit grew more in length than in width (Figures 1 and 2). This is the preferred fruit form for the national consumer market (Oliveira *et al.*, 2008). LDC was less in plants irrigated with saline water, independent of the presence of bovine bio-fertilizer or mulch (Figure 1A, 1B). With less saline water, bio-fertilizer in the soil produced fruits with LDC 9.9% greater than those without fertilizer. In plants irrigated with saline water, bovine-biofertilizer produced fruits with 20% greater LDC (Figure 1A).

The fruits of the plants irrigated with more saline water, with and without mulch, reduced their LDC values by 0.7 cm and 1.4 cm, respectively, compared to those irrigated with less saline water (Figure 1B). These results were generally greater than those reported by Costa *et al.* (2001) and Freire *et al.* (2010) for plants irrigated with highly saline water, compared to the poorer results obtained by Campos *et al.* (2007), who evaluated fruit length of yellow passion fruit with bovine bio-fertilizer and mulch.

EDC values ranged from 5.2 to 5.9 cm. More saline water reduced the EDC by 0.7 cm in the fruit of plants with soil protected by mulch (Figure 2). The largest mean fruit EDC values are in class 2

( $\geq 55$  to  $< 65$  mm) of the commercial fruit quality standards of the Brazilian program for improvement of commercial standards and packing of fruit and vegetable producers (Brasil, 2003), that is, in the optimum class, because according to Oliveira *et al.* (2008) fruit for industry processing must have a significant internal cavity to increase the yield of pulp and juice.

Rodrigues *et al.*, (2008), who studied yellow passion fruit treated with bio-fertilizer of natural mineral salts and Freire *et al.* (2010), who studied the effect of water salinity on the quality of yellow passion fruit fruits with bovine bio-fertilizer, both reported EDC values greater than those found in this study.

FFI values varied from 1.09 in fruits of plants with high salinity irrigation, without bio-fertilizer and with mulch, to 1.29 in plants irrigated with low saline water, with bio-fertilizer and without mulch (Figure 3). According to Fortaleza *et al.* (2005) and Farias *et al.* (2007), greater FFI is associated with more oval fruit; Oliveira *et al.*, (2008) reported that this type of fruit is more requested by the fresh fruit market and the processing industry, since it produces nearly 10% more juice than round fruits, although the latter are preferred by external markets (Salomão *et al.*, 2001). More saline water reduced the FFI, independently of the addition of organic material and soil cover.

In plants irrigated with non-saline water, the application of bovine bio-fertilizer increased the juice yield (JY) from 35.9% to 45.0%, an increase of 25.5%, and increased pulp yield (PY) by 21%.

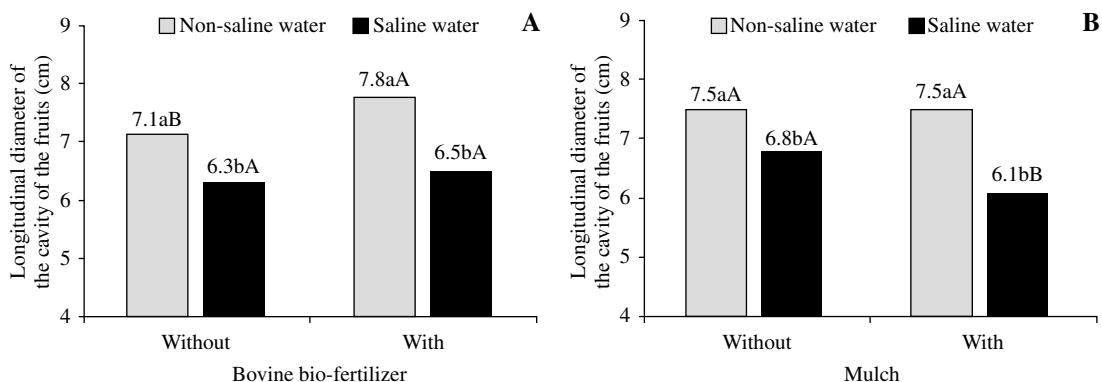


Figure 1. Longitudinal diameter of the cavity (LDC) of the fruits of yellow passion fruit produced in soil with and without bovine bio-fertilizer (A), with and without mulch (B) irrigated with greater and lower salt content. Means followed by the same lower case letter between salinity conditions in the same fertilizer condition, and upper case letters in the same salinity conditions but different fertilizer condition, are not statistically different by the F test ( $P \leq 0.05$ ).

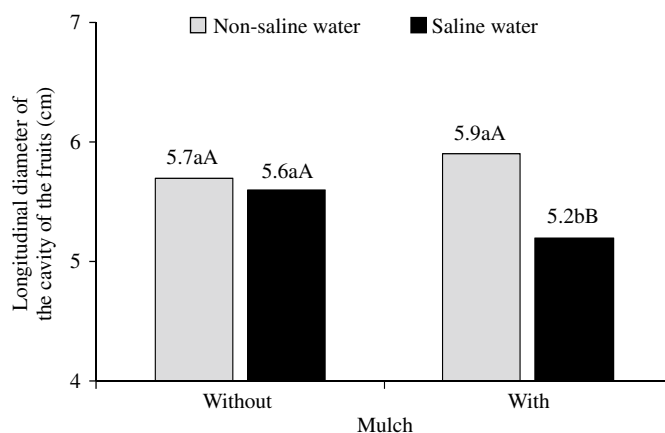


Figure 2. Equatorial diameter of the cavity (EDC) of yellow passion fruit produced in soil with and without bovine bio-fertilizer (A), with and without mulch (B) irrigated with greater and lower salt content. Means followed by the same lower case letter between salinity conditions in the same fertilizer condition, and upper case letters in the same salinity conditions but different fertilizer condition, are not statistically different by the F test ( $P \leq 0.05$ ).

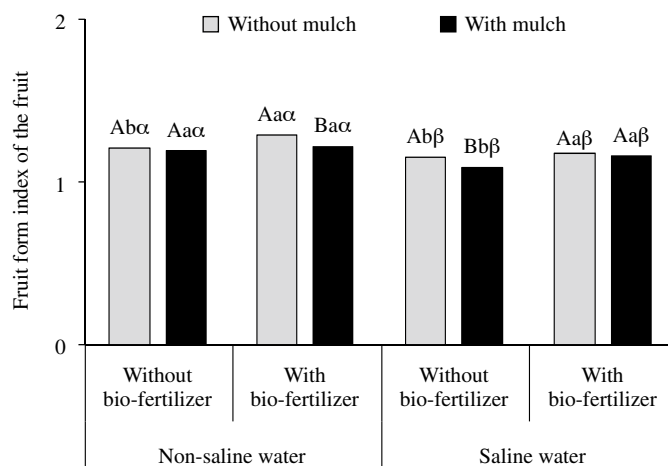


Figure 3. Fruit form index (FFI) of the fruits of yellow passion fruit produced in soil with and without bovine bio-fertilizer (A), with and without mulch (B) irrigated with greater and lower salt content. Means followed by the same lower case letter between salinity conditions in the same fertilizer condition, and upper case letters in the same salinity conditions but different fertilizer condition, are not statistically different by the F test ( $P \leq 0.05$ ).

Irrigation with saline water without bio-fertilizer increased juice and pulp yield by 19% and 16%, respectively. The use of soil cover increased juice yield from 38.8% to 42.1% (+8%) and pulp yield from 43.6% to 46.3% (+6%) in fruits of plants irrigated with non-saline water. However, the use of mulch reduced juice and pulp yield, the latter by 14% in plants irrigated with saline water (Table 2).

Similar effects were found on juice and pulp yield with bovine bio-fertilizer by Dias *et al.* (2011). According to the literature, the use of bovine bio-fertilizers in soil irrigated with saline water produces

an increase in the growth and production of crops, because they have organic solutes such as sugars, free amino acids and proline which increase the capacity of plants to adapt to the action of salts (Nardi *et al.*, 2002; Baalousha *et al.*, 2006), while in the absence of such fertilizer growth is quite reduced as a result of the toxic effect of the salts (Freire *et al.*, 2010; Dias *et al.*, 2011).

Overall, 49.2% of the PR in the treatments with bio-fertilizer irrigated with non-saline water and 49.3% of the treatments without mulch irrigated with saline water (Table 2) are compatible with the

Table 2. Juice and fruit pulp yield of the fruits of yellow passion fruit produced in soil with and without bovine bio-fertilizer (A), with and without mulch (B) irrigated with greater and lower salt content.

Water quality	Bovine bio-fertilizer		Mulch	
	Without	With	Without	With
			Juice yield (JY)	
Non-saline water	35.9 bB	45.0 aA	38.8 bA	42.1 aA
Saline water	42.6 aA	39.7 aA	43.9 aA	38.4 aB
			Pulp yield (PY)	
Non-saline water	40.6 bB	49.2 aA	43.6 bA	46.3 aA
Saline water	47.1 aA	44.7 bA	49.3 aA	42.5 aB

Means followed by the same lower case letter in columns between salinity conditions in the same fertilizer and mulch condition, and upper case letters in rows, in the same salinity conditions but different fertilizer and/or mulch condition, are not statistically different by the F test ( $P \leq 0.05$ ).

exigencies of the consumer market (50% PR) (Meletti *et al.*, 2002), while the mean percentage of JY was above the required yield of 33% (Haendler, 1965) and is also adequate for industry, which prefers fruit with high juice yield (Cavichioli *et al.*, 2008). This high JY may come from yellow passion fruits with a greater number of seeds due to the mucilaginous membrane (sarcotesta) which surrounds each seed.

The peel strength (PS) of the fruit (Figure 4) varied from 96.5 to 101.7 Newtons (N) in the fruits of plants irrigated with non-saline water and from 100.7 to 111.0 in treatments with saline water. These values are greater than those obtained by Rodrigues *et al.*, (2008) in treatments with bio-fertilizer based on natural mineral salts and organic compounds.

Except for the treatments with bio-fertilizer and without mulch (with saline and non-saline water), the other treatments showed an increase in PS in plants irrigated with saline water, which was greatest in the fruit of the treatment with bio-fertilizer and mulch. A greater PS value was also found in the treatment with bio-fertilizer and mulch with non-saline compared to the treatment without bovine bio-fertilizer, with mulch and non-saline water. This suggests that the increase in salt concentration in the water with higher ionic content associated with the presence of the organic solutes of bio-fertilizer due to greater calcium content produced more calcium pectate in the epicarpal cell wall of the fruits, with a consequent increase in peel strength (Rodrigues

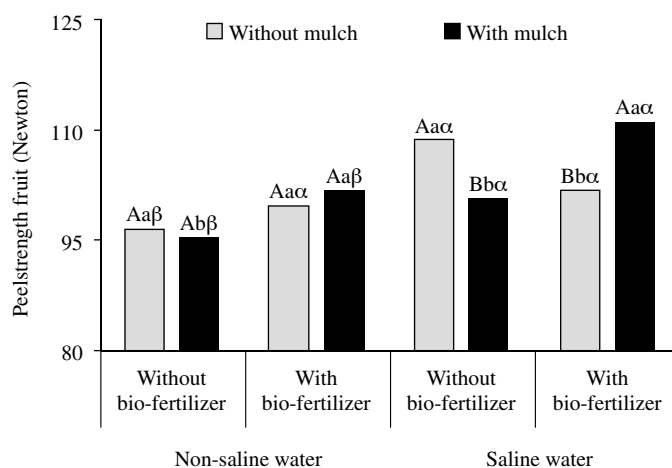


Figure 4. Peel strength (PS) of the fruits in yellow passion fruit watered with non-saline and saline water, in substrate with and without bovine-bio-fertilizer, and with and without mulch. Capital letters compare mulch with the same conditions of water salinity and use of bio-fertilizer; lower case letters compare bovine bio-fertilizer in the same conditions of water salinity and mulch; Greek letters compare water salinity under the same conditions of bovine bio-fertilizer and mulch. Means followed by the same letter are not statistically different (F test,  $P \leq 0.05$ ).

et al., 2008), which resulted in greater resistance to transport and longer post-harvest useful life (Vianna-Silva et al. 2008).

According to Lima & Yamanishi (2012), 74% of consumers observe the PS of the fruit before buying. This is one of the methods the consumer uses to determine the ripeness and conservation state of the fruit and thus not be fooled when buying the product.

### Conclusions

The greatest values of the longitudinal cavity diameter (LDC) and the equatorial cavity diameter

(EDC), fruit form index (FFI), juice yield (JY) and pulp yield (PY) were obtained with the use of bovine bio-fertilizer and mulch in the substrates irrigated with non-saline water.

The use of non-saline water reduced the longitudinal cavity diameter (LDC), equatorial cavity diameter (EDC) and the fruit form index (FFI) independent of the presence of organic additives in the substrate and increased the juice yield (JY), pulp yield (PY) and peel strength (PS) in the treatments without bio-fertilizer or mulch.

The yellow passion fruit with greatest fruit form index (FFI) showed the best juice yield (JY).

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