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Beet Crop under Different Fertilization and Nitrogen Fertigation in Protected Environment

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Abstract

Chemical fertilizers have been increasingly used in agriculture. The application of these nutrients via irrigation water has been evaluated in order to obtain productive results in agricultural yield. The objective of this research was to evaluate the effect of nitrogen (N) doses, applied by fertigation and associated with different types of basal fertilization, on the growth and production of beet. The experiment was conducted at the Federal University of Campina Grande (UFCG), in a protected environment belonging to the Academic Unit of Agricultural Engineering (UAEA). The adopted statistical design was completely randomized blocks, with three replicates, and the factors were arranged in a 5 × 3 factorial scheme, corresponding to five N doses (0, 50, 100, 150 and 200 mg dm^{-3} of soil), and three types basal fertilization (soil without fertilizer, earthworm humus, earthworm humus + NPK). At 45 days after transplanting, the number of leaves per plant, plant height, stem diameter, leaf area, green intensity, bulb diameter, stem length, bulb fresh weight, bulb dry weight and total soluble solids (°Brix) were quantified. Both Soil basal fertilization significantly influenced beet growth and production, and the treatment with earthworm humus and earthworm humus + NPK led to the best results for the analyzed variables. The highest N dose promoted the best performance for stem diameter and content of total soluble solids (°Brix).

Keywords: *Beta vulgaris* L., °Brix, nitrogen fertilization, olericulture, production

1. Introduction

Beet (*Beta vulgaris* L.) is plant of the *Amaranthaceae* family, originated in Europe. It has high nutritional value and stands out among the vegetables for its nutritional composition, particularly rich in sugars, B-complex vitamins and nutrients such as potassium, sodium, iron, copper and zinc, and its roots, tubers and leaves can be consumed (Trani et al., 2013).

Silva et al. (2015) report that, for the beet crop, there is little information in the literature, especially on its nutritional demand and utilization of fertigation, thus requiring studies on different types of basal fertilization and nitrogen fertigation, because the productive gains of the crop in height and yield with these techniques are still little studied in the country.

Fertigation consists in the split application of water-soluble fertilizers through the irrigation system along the cycle in crop water management. This technique translates the efficient use of fertilizers in the irrigated agriculture, because it increases the effectiveness of the use of fertilizers and supplies nutrients in the soil volume explored by the root system of the crops, adjusting to their needs in the different phenological stages (Coelho et al., 2014).

Nitrogen (N) is an essential element for plants and its low availability in the associated with poor absorption by plants substantially limits the vegetative growth. It is a constituent of amino acids and necessary for the synthesis of chlorophyll, exerting influence on the photosynthetic process (Marenco & Lopes, 2009).

Since it is a crop mainly produced by small and medium farmers, located in the green belts of the large cities, the beet crop extracts high quantities of N; however, due to the high volatilization of this nutrient when applied only at planting, the nutritional demand of this crop during the cycle may not be fully met.

Given the above, this study aimed to evaluate the effect of N doses, applied via fertigation and associated with different types of basal fertilization, on the growth and production of the beet crop.

2. Material and Methods

The experiment was carried out from June to August 2016 in a greenhouse of the Academic Unit of Agricultural Engineering (UAEAg), at the Federal University of Campina Grande, Campina Grande, PB, Brazil. The greenhouse is 15 m long, 10 m wide, with ceiling height of 3 m, covered by 13-micron-thick transparent low-density polyethylene film and shade screen on the sides.

The physical and chemical characteristics of the soil and humus used in the experiment, in the layer of 0.0-0.2 m, are presented in Tables 1 and 2 (Embrapa, 2013).

Table 1. Physical and chemical characteristics of the soil used in the experiment in the layer of 0.0-0.2 m

pH	M.O.	P	K	Na	Ca	Mg	Al	H
	----- %----	-- mg/100 g --	mmol$_c$dm^{-3}					
5.9	0.65	1.43	0.14	0.07	1.9	0.66	0.2	1.88
Density	Sand	Silt	Clay					
g cm^{-3}	%							
1.39	74.7	16.11	9.19					

Table 2. Chemical characteristics of the earthworm humus used in the experiment

pH	M.O.	P	K	Na	Ca	Mg	Al	SB	CTC	V	m
	--- gkg^{-1} ---	------ mgdm^{-3} ------		Cmol$_c$ dm^{-3}						-------- % -------	
6.95	73.13	469.31	656	0.98	13.25	1.05	0	18.96	20.79	91.24	0

The data concerning temperature and relative humidity of the air, during the experimental period, were collected from the sensors installed inside the greenhouse (Figures 1A and 1B).

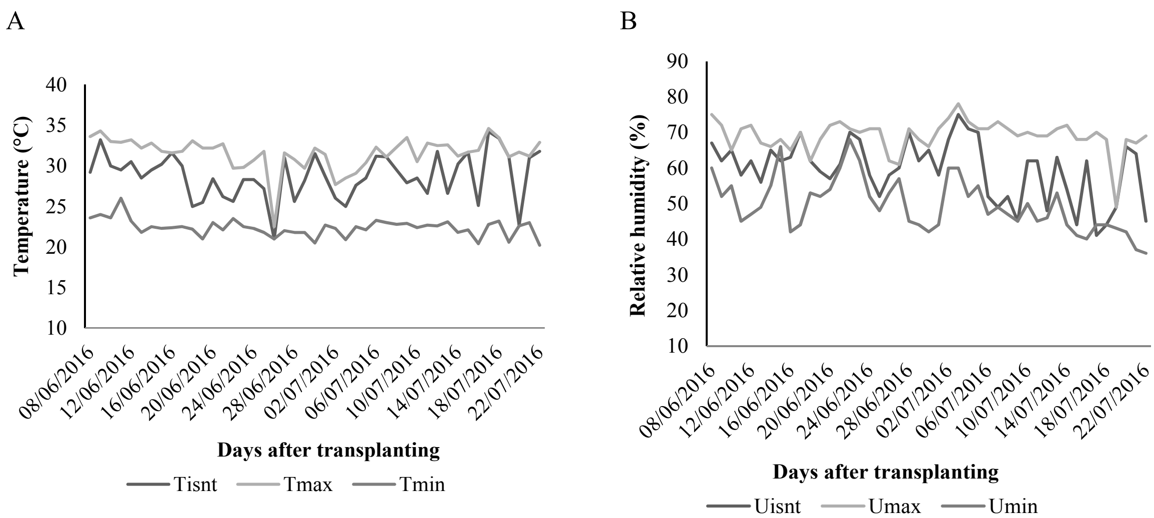

Figure 1. Instantaneous, maximum and minimum air temperature (1A) and relative humidity of the instantaneous, maximum and minimum air (1B) during the experimental period, Campina Grande, PB

The treatments were formed by the combination of two factors: five doses of N fertilization applied via fertigation (0; 50; 100; 150 and 200 mg of N dm^{-3} of soil) and three types of basal fertilization soil without fertilization – control (A0), earthworm humus (A1), earthworm humus + NPK (A2). Urea was used as N source and the N doses corresponded to 0, 0.7, 1.4, 2.1 and 2.8 g pot^{-1}, according to the methodology proposed by Silva and Silveira (2012), split into three applications: the first one at 20 days after transplanting (DAT), second one at 40 DAT and third one at 60 DAT.

The adopted statistical design was completely randomized blocks, with three replicates, and the studied factors were arranged in a 5 × 3 factorial scheme. The 15 treatments were arranged in 45 plots, *i.e.*, 45 cylindrical 12 L pots spaced by 0.5 m between plants and 1.0 m between rows. Each experimental unit was composed of a pot with holes at the bottom, containing a 1cm layer of crushed stone nº 1, covered by geotextile to facilitate drainage; the pots were filled with approximately 14 dm^3 of soil.

The experiment used the beet cultivar "Early Wonder", one of the most cultivated in Northeast Brazil by small vegetable producers. The seedlings were produced on expanded polyethylene trays of 128 cells, filled with commercial substrate. Transplanting was performed using two seedlings per pot, approximately 20 days after sowing.

A drip irrigation system was used with pressure-compensating emitters with nominal flow rate of 2.3 L h^{-1}, attached to the irrigation lines (16 mm diameter polyethylene tubes), with valves installed at the beginning of each line, which allowed to differentiate the application of the N doses via fertigation per treatment, and a flow meter at the beginning of the controller to record the water volume per lateral line, a condition that is indispensable for the control of irrigation and fertigation management.

Pumping was made using a centrifuge motor pump and a 1-inch screen filter, with flow rate capacity of 5 m^3 h^{-1}, to avoid the entry of suspended particles in the system with sizes larger than the diameter of the emitters.

Irrigation management was daily performed, based on the method of (Hargreaves & Samani, 1985), which requires only temperature data, and the equation showed the following form (Jensen et al., 1990; Pereira et al., 1997), adapted to the symbols used here (Equation 1). This method of determination of reference evapotranspiration has been very useful for the management of irrigation in pots, due to its practicality, since it uses easily available meteorological elements such as temperature and relative humidity in addition to knowing the area of the pot (Rodrigues et al., 2013, Santos et al., 2016).

$$ET_0 = 0.0023Ra(T_{max} - T_{min})^{0.5}(T_{md} + 17.8) \quad (1)$$

Where,

ET_0: Reference evapotranspiration, mm d^{-1}; Ra: extraterrestrial radiation, mm d^{-1}; T_{max}: maximum temperature, in °C; T_{min}: minimum temperature, in °C; and T_{md}: mean daily temperature = $0.5(T_{max} + T_{min})$, in °C.

Hence, crop evapotranspiration, *i.e.*, the water volume that must be replaced, consumed by the crop of economic interest, which varies according to crop development stages from crop, was obtained by multiplying the reference evapotranspiration (ET_0) by the crop coefficient (Kc) of 0.50; 0.75; 1.10 and 0.90 adapted from Doorenbos and Pruitt (1977), according to Equation 2.

$$ETc = ET_0 \times Kc \quad (2)$$

Where,

ETc: Crop evapotranspiration, mm d^{-1}; ET_0: Reference evapotranspiration, mm d^{-1}; Kc: Crop coefficient.

At 45 DAT, the following variables were analyzed: number of leaves per plant, plant height, stem diameter, leaf area, green intensity, bulb diameter, stem length, bulb fresh weight, bulb dry weight and total soluble solids (ºBrix).

The number of leaves was determined by counting the leaves of each plant; plant height was measured using a tape measure; stem diameter, bulb diameter and bulb length were measured with a digital caliper; green intensity was determined in the fourth fully expanded leaf, from the apex. The measurements were taken between 9:00 and 9:30 a.m., using the portable chlorophyll meter SPAD-502 (Minolta Camera Co. Ltda). Five measurements of the SPAD index were taken per leaf, in the central region of leaf blade of each plant in the evaluation plot, and the mean value was used to represent the treatments. Leaf area was determined according to Equation 3, following the methodology proposed by Marrocos et al. (2010).

$$LA = L \times W \times f \quad (3)$$

Where,

LA = leaf area (cm^2); L = leaf length (cm); W = leaf width (cm); f = correction factor for beet (0.69), dimensionless, according to the methodology proposed by Marrocos et al. (2010).

The content of total soluble solids (°Brix) was analyzed using a portable manual refractometer. Bulb fresh weight was determined using a digital scale with three decimal places of accuracy, in g. After drying the material in an oven at 60 ºC, bulb dry weight was determined on a digital scale with three decimal places of accuracy, in g.

The variables were statistically analyzed by F test, with follow-up analysis always in case of significant interaction. The quantitative factor relative to the N doses was statistically analyzed through polynomial regression (linear and quadratic) and the types of basal fertilization were analyzed by Tukey test at 0.05 probability level, using the computer program Sisvar (Ferreira, 2008).

3. Results and Discussion

The summary of the analysis of variance for the variables number of leaves (NL), plant height (PH), stem diameter (SD), leaf area (LA) and green intensity (GI) of beet plants cultivated under different types of basal fertilization and N fertigation at 45 DAT is shown in Table 3. There was effect of the types of fertilization at 0.01 and 0.05 probability levels by F test, on all growth variables, except number of leaves. For the factor fertigation, there was significant effect on the variables plant height and stem diameter at 0.01 probability level by F test (Table 3). There was no significant effect of the interaction between the types of fertilization (A) and N fertigation (F) on the beet crop at 45 DAT (Table 3).

Table 3. Summary of the analysis of variance for number of leaves (NL), plant height (PH), stem diameter (SD), leaf area (LA) and green intensity (GI) of beet plants under different types of basal fertilization and N doses applied via fertigation at 45 days after transplanting

Sources of Variation	G.L.	NL	PH (cm)	SD (mm)	LA (cm^2)	GI
Types of Fertilization (A)	2	0.15^{ns}	414.43^{**}	42.05^{*}	99.19^{**}	208.34^{**}
Fertigation (F)	4	1.81^{ns}	202.43^{**}	146.82^{**}	19.40^{ns}	40.74^{ns}
Interaction (A × F)	8	1.21^{ns}	10.64^{ns}	14.99^{ns}	9.31^{ns}	19.56^{ns}
Residue	28	1.23	16.48	9.31	9.37	19.68
General Media	-	6.95	30.53	13.74	22.22	32.21
Coefficient of variation (%)	-	15.99	13.30	22.21	13.78	13.78

Note. * And ** significant at 5 and 1% probability, respectively, ^{ns} not significant.

Plant height as a function of basal fertilization showed better performance for the fertilizations with humus = A1 and humus + NPK = A2, compared with the control, which contained only the nutrients present in the soil analysis (Figure 2A).

Marques et al. (2010), in a study on beet production and quality as a function of organic fertilization, claimed that there was no difference between the effects on the growth parameters, disagreeing with the results found in the present study. This fact is possibly related to the composition of the types of mineral fertilizers used in the present study, which are rich in nutrients and readily available to plants. Kist et al. (2007) state that nitrogen compounds such as earthworm humus have a high content of organic material, it helps in the physical and biological structure of the soil, as well as neutralizes pH, acts as a chemical fertilizer, making nutrients more readily assimilable by crops.

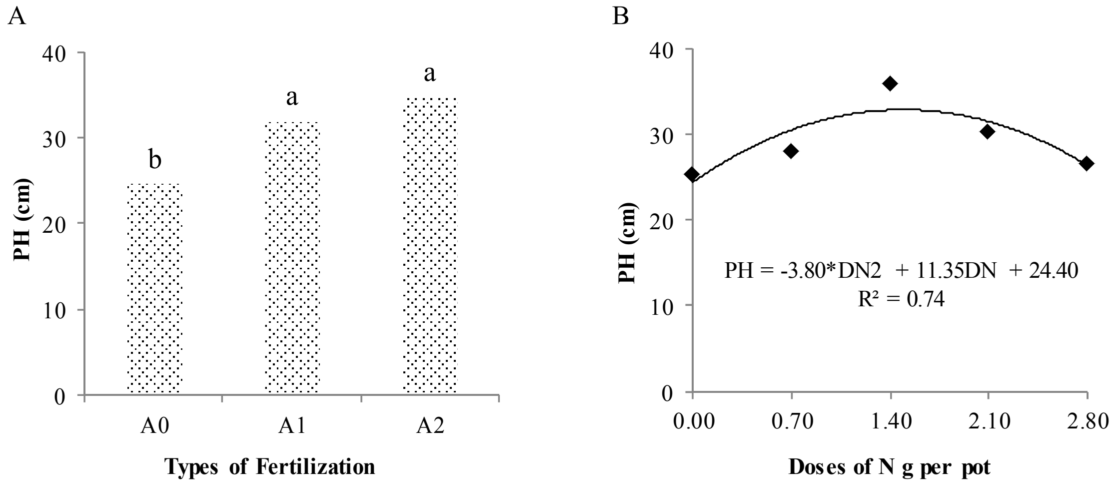

Figure 2. Height of plants according to the types of fertilization: control - A0, earthworm humus - A1, earthworm humus + NPK - A2 (A) and nitrogen doses: 0, 0.7, 1.4, 2.1 and 2.8 g pot^{-1} (B) of the beet at 45 days after transplanting

The increment of N dose applied via fertigation significantly increased PH in the beet crop and the highest value occurred at the N dose of 1.4 g pot^{-1}, equal to 32.87 cm (Figure 2B).

Silva et al. (2015) state that the average height of the plants evaluated at 50 DAT, for the cultivar "Early Wonder", was 40 cm with the utilization of mineral fertilizer. These results agree with those obtained in the present study, since the plants were only at 45 days after transplanting.

There were significant differences for the variable SD as a function of the types of basal fertilization, but there was no significant difference between the treatment humus and earthworm humus + NPK, and the highest relative means were observed in the treatment with earthworm humus + NPK, corresponding to 14.78 mm (Figure 3A). According to Malavolta (1980), the responses of both growth and crop production are related to the nitrogen content present in the soil, available to the plants, either in the form earthworm humus organic fertilizer or even supplied as a chemical fertilizer in many cases using urea.

Silva et al. (2016), studying radish production as a function of doses of organic fertilization, observed that it did not differ from the treatments with application of organomineral fertilization for the growth variables of the radish crop.

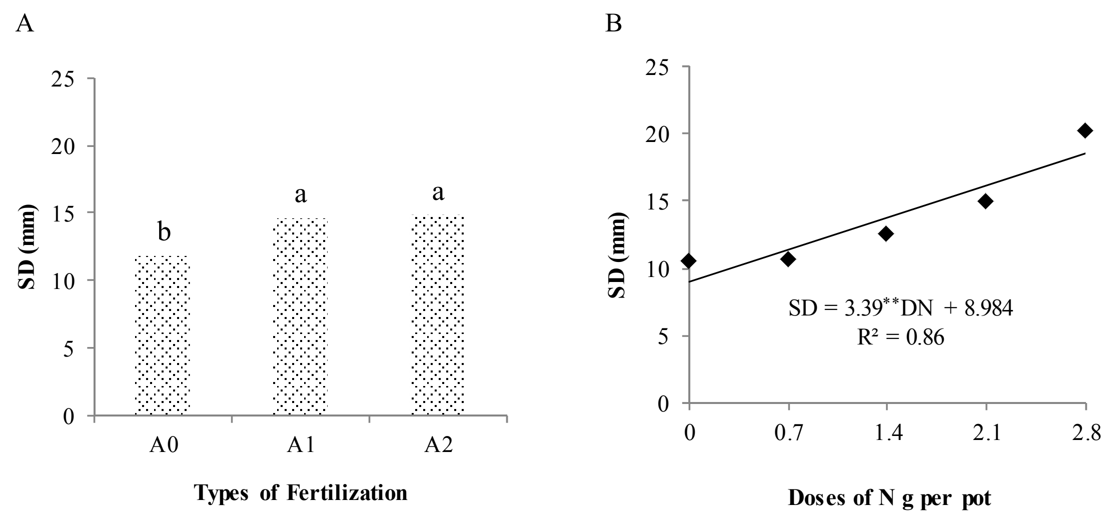

Figure 3. Stem diameter according to the types of fertilization: control - A0, earthworm humus - A1, earthworm humus + NPK - A2 (A) and nitrogen doses: 0, 0.7, 1.4, 2.1 and 2.8 g pot^{-1} (B) of the beet at 45 days after transplanting

The increment of N dose applied via fertigation significantly increased SD in the beet cultivar "Early Wonder", and the highest value occurred at the N dose of 2.8 g pot^{-1}, equal to 20.20 mm (Figure 4B).

The different basal fertilizations differed statistically at 0.05 probability level by Tukey test, for the variable LA (Figure 4A). The treatment with best result was humus + NPK, followed by that with earthworm humus. The best results evidenced in the treatments with earthworm humus and humus + NPK are related to the N contents in these treatments. Earthworm humus is one of the organic fertilizers widely known as rich in N, an essential element for plant development, favoring both the vegetative growth and significant increments in the beet commercial yield (Filgueira, 2008).

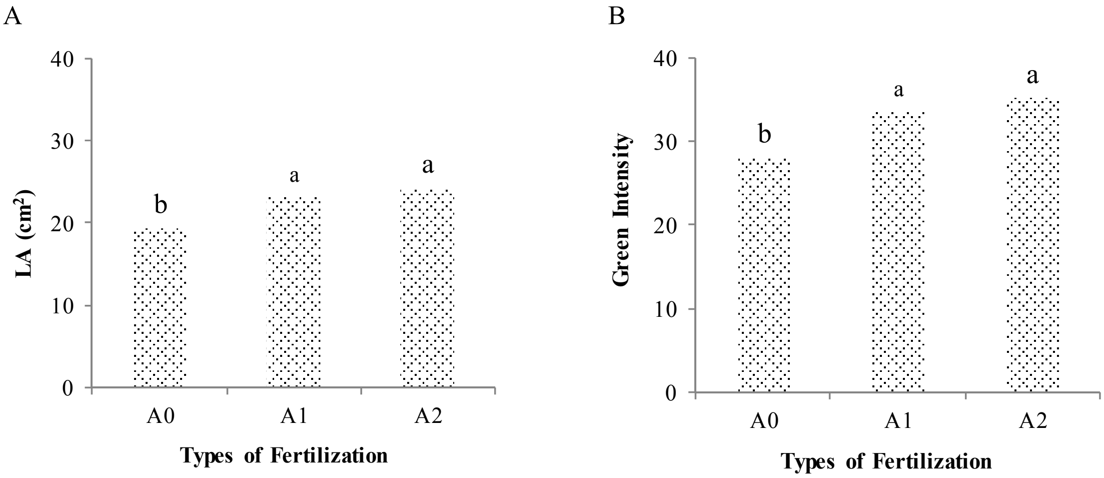

Figure 4. Leaf area according to the types of fertilization: control - A0, earthworm humus - A1, earthworm humus + NPK - A2 (A) and nitrogen doses: 0, 0.7, 1.4, 2.1 and 2.8 g pot^{-1} (B) of the beet at 45 days after transplanting

There were significant differences for green intensity, or the estimated reading of the chlorophyll meter, in SPAD units, as a function of the types of basal fertilization, but there was no significant difference between the treatments of earthworm humus = A1 and earthworm humus + NPK = A2, and the highest results occurred in the treatment with earthworm humus + NPK, corresponding to 35.09 SPAD units (Figure 5B).

According to Silva et al. (2009), the SPAD index increases with the increment in N content available to plants, which agrees with the data of the present study, since the treatment with earthworm humus + NPK promoted highest content of N available to beet plants.

The summary of the analysis of variance for the variables BD, BL, BFW, BDW and °Brix of beet plants as a function of the types of basal fertilization and N fertigation doses at 45 days after transplanting is presented in Table 4.

There was effect of the type of basal fertilization at 0.01 probability level for BD, BL, BFW and BDW. It is noted that, for the factor fertigation doses, the effect was significant at 0.01 probability level for the variable ºBrix, or content of total soluble solids. There was no significant effect for the interaction between the studied factors, Fertilization x Fertigation (Table 4).

Table 4. Summary of the analysis of variance for the variables bulb diameter (BD), bulb length (BL), bulb fresh weight (BFW), bulb dry weight (BDW) and °Brix of beet plants under different types of basal fertilization and N doses applied via fertigation at 45 days after transplanting

Sources of Variation	G.L.	BD (mm)	BL (mm)	MFW (g)	MSW (g)	°Brix
Types of Fertilization (A)	2	1436.12^{**}	226.16^{**}	992.12^{**}	4.98^{**}	14.22^{ns}
Fertigation (F)	4	34.97^{ns}	46.92^{ns}	16.69^{ns}	0.15^{ns}	20.41^{**}
Interaction (A × F)	8	13.61^{ns}	26.14^{ns}	3.92^{ns}	0.13^{ns}	9.31^{ns}
Residue	28	14.74	35.67	4.17	0.07	4.36
General Media	-	20.87	33.95	11.18	1.18	5.73
Coefficient of variation (%)	-	18.40	17.59	18.28	23.20	36.34

Note. * And ** significant at 5 and 1% probability, respectively, ns not significant.

Bulb diameter and bulb length of the beet crop under different types of fertilization and N fertigation at 45 days after transplanting are presented in Figure 5. There was significant difference at 0.05 probability level by Tukey test, and the treatments with application of earthworm humus and earthworm humus + NPK led to the best values of bulb diameter and bulb length, corresponding to 27.2 and 36.2 mm, respectively (Figures 5A and 5B). Sediyama et al. (2009) concluded in his studies that the application of organic compounds when compared to treatments without fertilization, stimulates the nitrogen content in the plant, in this way only organic fertilization is able to supply the nutritional needs, since the plants are well nourished in nitrogen.

Silva et al. (2016) obtained higher values of bulb length and bulb diameter with organic fertilization, compared with mineral fertilization, equal to 5.7 cm and 6.5 cm, respectively. These values are higher than those observed in the present study, which may be related to the younger age of the plants.

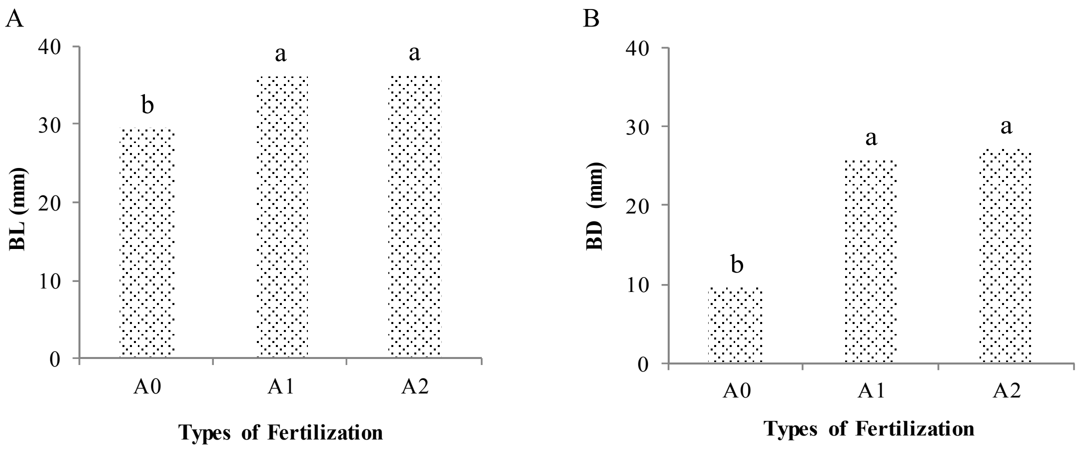

Figure 5. Bulb diameter according to the types of fertilization: control - A0, earthworm humus - A1, earthworm humus + NPK - A2 (5A) and nitrogen doses: 0, 0.7, 1.4, 2.1 and 2.8 g pot^{-1} (5B) of the beet at 45 days after transplanting

Bulb fresh weight and bulb dry weight as a function of the basal fertilization showed better performance in the fertilizations with earthworm humus and earthworm humus + NPK, compared with the control, which contained only the nutrients present in the soil analysis (Figures 6A and 6B). Oliveira et al. (2010) report in their studies that organic fertilization and associated with mineral fertilization positively influence the yield of the crops, since the nutrients are not easily lost by leaching or volatilization.

Damasceno et al. (2011), studying beet yield as a function of N doses, observed that as the N dose increased there was an increment in bulb fresh phytomass. Aquino et al. (2006) report that up to a certain limit, increments in N availability to beet plants promote increase in leaf area, which leads to increase in bulb yield.

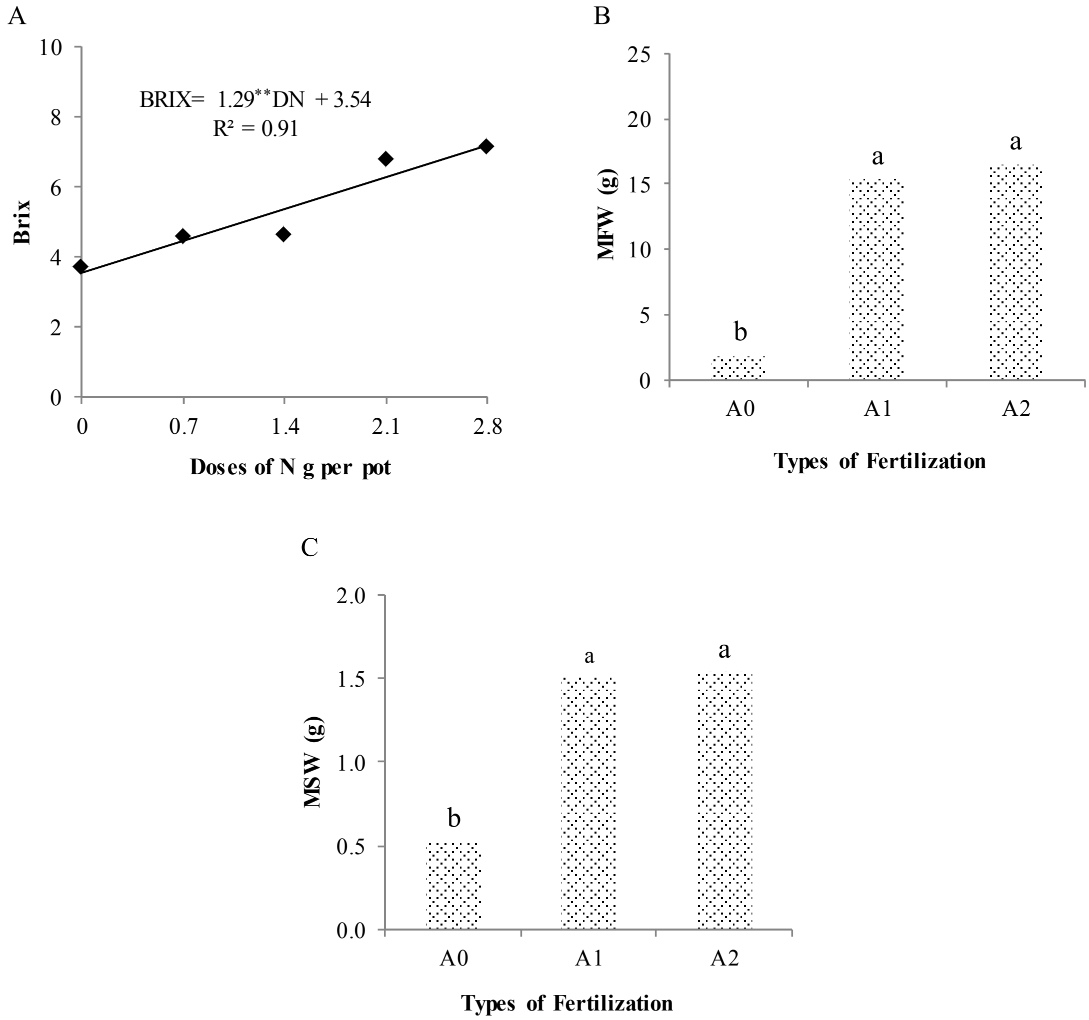

Figure 6. Bulb dry mass (A), Fresh bulb mass (B) according the types of fertilization: control - A0, earthworm humus - A1, earthworm humus + NPK - A2, and ºBrix according to nitrogen doses: 0, 0.7, 1.4, 2.1 and 2.8 g pot^{-1} (C) of the beet at 45 days after transplanting

According to the obtained regression equation, the ºBrix content of the beet crop increased with the increment in N dose applied via fertigation, and the highest value occurred at the N dose of 2.8 g pot^{-1}, equal to 7.15 °Brix. The increment per unit increase in the N dose is equal to 1.29 °Brix (Figure 6A).

Marques et al. (2010), applying organic fertilizer with N content of 2.26 g kg^{-1} plus 0.77 g of N Kg^{-1} of soil, obtained values from 10.26 to 11.10 ºBrix, which are higher than those obtained in the present study.

4. Conclusions

Basal fertilization (earthworm humus and earthworm humus + NPK) significantly influenced the growth and production variables of the beet crop at 45 days after transplanting.

The highest values of the variables plant height, stem diameter, leaf area, green intensity, bulb diameter, bulb length, bulb fresh weight and bulb dry weight were observed in the treatment with earthworm humus and earthworm humus + NPK at 45 days after transplanting.

The N dose of 2.8 g pot^{-1} corresponding to 6.22 g of urea plant^{-1} led to the highest values of stem diameter and content of total soluble solids (°Brix) at 45 days after transplanting in the beet crop.

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