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GROWTH, GAS EXCHANGE AND YIELD OF CORN WHEN FERTIGATED WITH BOVINE BIOFERTILIZER[1]

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ABSTRACT - The bovine biofertilizer applied through irrigation water in the soil (bio fertigation), can be a viable organic source to maintain fertility levels in agricultural production systems. So, this work was aimed at evaluating the effects of different concentrations of bovine biofertilizer applied by fertigation on corn growth, gas exchange and yield. The experiment was conducted under full sun exposure, in Fortaleza, Ceara, in 100 liter (100 L) vessels. The experimental design was that of randomized blocks with five treatments and five repetitions. Treatments consisted of 0.5 L doses (per plant) of a fertigating solution (biofertilizer + water) weekly applied, with a different biofertilizer concentration to each treatment, as follows: C0 = 0% biofertilizer (control), C1 = 12.5%, C2 = 25% biofertilizer, C3=50% biofertilizer, C4 = 100% biofertilizer. We analyzed the effects on the following variables: plant height, stem diameter, leaf number, shoot dry weight, photosynthesis, stomatal conductance, transpiration and yield. The biofertilizer was the most efficient considering the initial growth and gas exchange. Also, the bovine biofertilizer treatments (as a whole) favored the increase in the weight of 1000 seeds and grain yield.

Keywords: *Zea mays L.* Organic input. Photosynthes

CRESCIMENTO, TROCAS GASOSAS E PRODUTIVIDADE DO MILHO FERTIRRIGADO COM BIOFERTILIZANTE BOVINO

RESUMO - O biofertilizante bovino, aplicado via água de irrigação no solo, constitui-se em uma fonte orgânica viável para manutenção dos níveis de fertilidade em sistemas de produção agrícola. Nesse sentido, o trabalho teve como objetivo avaliar diferentes concentrações de biofertilizante bovino, aplicadas via fertirrigação, no crescimento, nas trocas gasosas e na produtividade da cultura do milho. O experimento foi conduzido a pleno sol, em Fortaleza, Ceará, em vasos com volume de 100 L. O delineamento experimental foi em blocos casualizados com cinco tratamentos e com cinco repetições. Aplicaram-se semanalmente 0,5 L por planta de uma solução fertirrigante (biofertilizante + água), diferenciada quanto à concentração do insumo orgânico, em conformidade com os tratamentos: C0 = 0% (testemunha); C1 = 12,5%; C2 = 25%; C3 = 50%; C4 = 100% de biofertilizante. Foram analisadas as seguintes variáveis: altura de plantas, diâmetro do colmo, número de folhas, matéria seca da parte aérea, fotossíntese, condutância estomática, transpiração e produtividade. O biofertilizante foi a mais eficiente quanto ao crescimento inicial e as trocas gasosas. Os tratamentos com biofertilizante bovino favoreceram o incremento no peso de 1000 sementes e na produtividade de grãos.

Palavras chave: *Zea mays L.*Insumo orgânico. Fotossíntese

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INTRODUCTION

Corn (*Zea mays* L.) belongs to the Gramineae family, one of the most efficient energy storage plants that exists in nature and in one of the main cereals produced in Brazil. Originally from central America, it is cultivated in all of Brazil and has a great economic importance due to various forms of use as human and animal food and in the high tech industry in the production of biofuels (FORNASIERI FILHO, 2007).

The importance of the use of liquid biofertilizers in the plain or enriched fermented microbial form, is in the quantitative of the elements, in the diversity of mineral nutrients and the availability of nutrients through biological activity (ALVES et al., 2001; ALVES et al., 2009). Some studies have demonstrated the possibility of biofertilizer in the soil as a source of fertilizer to meet the nutritional requirements of plant growth, gas exchange and productivity (BRAGA, 2010; DINIZ et al., 2011).

The use of this organic input becomes a viable and economic alternative as an organic source for small and medium producers, since it enhances fertility and soil conservation (ARAÚJO et al., 2007) and product quality (RODRIGUES et al., 2008). It has in its composition, nutrients that are more readily available compared to other organic fertilizers and may promote the improvement of the chemical properties, because the supply of biofertilizers in the soil increases the K, Ca and Mg levels (ALVES et al., 2009).

There was an increase in corn production in single application of bovine manure based organic fertilizer or combined with chemical fertilization (CANCELLIER et al., 2011). It should be noted that, the addition of organic materials is essential to the quality of the soil, characterized by a slow release of nutrients, which reduces processes such as leaching, fixation and volatilization.

Even though there are publications about the use of organic sources, such as bovine bio-fertilizer and bovine manure in the fertilizer management of the corn crop (OLIVEIRA et al., 2011; CANCELLIER et al., 2011; SOUSA et al., 2012), there is still a small amount of available information based on scientific studies on the effect of these inputs applied by fertirrigation and at different concentrations related to exchanges (photosynthesis, stomatal conductance and transpiration).

With this information, this research aimed with to evaluate different concentrations of bovine biofertilizer applied through fertigation in the growth, gas exchanges and yield of the corn crop.

MATERIALS AND METHODS

The study was conducted in the experimental are of the Agro Meteorological Station, on the Pici Campus of the Federal University of Ceara, in Fortaleza, Ceara, Brazil (3°45’S; 38° 33’W; 19 m). The physical and chemical characteristics of the substrate used (composed of soil+manure+sand), before the application of treatments, are presented in Table 1, according to Embrapa (1997) and Richards (1954).

Table 1. Values of some physical and chemical properties of the substrate before application of treatments used in experi-

Characteristics	Depth (0-20 cm)
Textural class	Sandy loams
Soil density (kg dm^{-3})	1.4
Ca ($cmol_c$ dm^{-3})	0.8
Mg ($cmol_c$ dm^{-3})	0.6
K ($cmol_c$ dm^{-3})	0.07
Na ($cmol_c$ dm^{-3})	0.03
H+Al ($cmol_c$ dm^{-3})	1.65
Al ($cmol_c$ dm^{-3})	0.4
ESP (%)[1]	1
pH (H_2O 1:2.5)	5.2
EC (dS m^{-1})[2]	0.22

[1]ESP = exchangeable sodium percentage; [2]EC = electrical conductivity of the extract soil: water

The planting of the AG 1051 hybrid corn seeds, was done in plastic pots with a 100 liter capacity, containing a mixture composed of soil, manure and sand, the ratio of 1:1:1, respectively. The planting was done in May of 2010, in which four plants were planted in each pot, and after the establishment of the seedlings, on the eighth day after sowing (DAS), the pots were pared down to one plant per pot.

The experimental design was a randomized block with five treatments and five repetitions. During the experiment, 0.5 L of a fertirrigante solution (biofertilizer + water) was applied weekly, different in its concentration of organic feedstock in accordance with the following treatments: C0 = 0% (control); C1 = 12,5%; C2 = 25%; C3 = 50%; C4 = 100% of biofertilizer.

The biofertilizer was prepared through anaerobic fermentation containing fresh bovine manure and water in the ratio of 50% (v/v), for a period of thirty to sixty days, in a plastic container, without the presence of air. To obtain the anaerobic system, the mixture was placed in a 240 liter plastic container leaving an empty space of 20 cm inside and hermetically sealed. The lid was fitted with a hose with the other end immersed in a container filled with 20 cm of water for the exit of gases (PENTEADO, 2007). The mineral element content present in the biofertilizer is shown in Table 2. Analyses were performed by adopting the suggested methodologies by Malavolta et al. (1997).

Table 2. Chemical characteristics of bovine biofertilizer used in fertigation of corn, Fortaleza, 2011.

Nutrients	N	P	K	Ca	Mg	S	Fe	Cu	Zn	Mn
	g L^{-1}						mg L^{-1}			
Biofertilizier	0,3	1,1	2,3	3,2	0,3	-	43,6	0,1	7,3	6,6

The experiment was irrigated by an auto-compensating drip system with a flow of 8 L h^{-1}, with a daily irrigation blade equivalent to 75% of the evaporation measured in a class A tank.

The fertigation was carried out every 15 days, starting with the 15th day after planting with a 0.5 CV centrifugal pump. Prior to fertigation, a washing is done in the system in order to prevent clogging of the drippers.

The amount of bovine biofertilizer applied was sized based on the suggestion of Santos (1992), who recommended a dose of 15 liters m^{-2} per month, therefore, two liters of the input per pot per month was supplied, with an area of 0.13 m^2, divided into four weekly applications of 0.5 liters of the solution with biofertilizer.

At 60 DAS, the following characteristics: number of leaves, plant height (cm), stem diameter (mm) and shoot dry matter (g) were analyzed. In the same period, the following physiological variables: net photosynthetic rate (μmol $m^{-2\ s-1}$), transpiration rate (mmol $m^{2-\ s-1}$) and stomatal conductance (mol m^{2} $^{-}$ s^{-1}) were obtained in fully expanded leaves, utilizing an infrared gas analyzer (ADC System, Hoddesdon, UK) in an open system, with air flow of 300 mL min^{-1}. Measurements of gas exchanges occurred between 10:00 and 11:00 o'clock.

Plants were harvested at 90 DAS and the following variables of productivity were analyzed: the husked ear weight (g), dehusked ear weight (g), weight of 1000 kernels (g) and kernel yield (kg ha^{-1}). The variables were analyzed statistically using the program Assistat (SILVA; AZEVEDO, 2009).

RESULTS AND DISCUSSION

The mean square values of the data obtained for the measured characteristics of the corn crop are shown in Table 3. According to variance analysis, it was found that concentrations of bovine biofertilizer significantly influenced plant height (PH), stem diameter (SD), leaf area (LA), shoot dry matter (SDM), stomatal conductance (SC) and photosynthesis (E).

The variation in the number of leaves using concentrations of biofertilizer (Figure 1A), at 60 DAS, constitutes a linear regression with a determining coefficient of 0.70. The superiority of the number of leaves in the largest concentrations of bovine biofertilizer shows the expressive effects of this source of organic fertilizer for corn crops, grown in pots, which consequently result in the higher efficiency of plants in the photosynthetic processes and transport of organic solutes in plant tissues. Taiz and Zeiger (2009), also discuss this subject. According to these authors the report that the supply inappropriate essential elements to plants cause disturbances in metabolic and physiological processes of plants.

Cavalcante et al. (2009) argue that, regardless of the time of application, the increase of the percentage of fermented liquid bovine manure in the substrate stimulates the initial growth of plants. Lima et al. (2011), in assessing organic waste as a nutrient source for growing Physic nut, also found similar results to this study for the number of leaves.

The variation in plant height with the increasing concentrations of bovine biofertilizer (Figure 1B) was also a linear model, with a determining coefficient of 0.95. The superiority of C4 concentration (100%) in relation to others, surely, is related to the presence of nitrogen in bovine biofertilizer (Table 2), which favors the growth of plants, because it is made up of amino acids and proteins (TAIZ; ZEIGER, 2009). Working in greenhouse conditions, Saraiva et al. (2010) also observed similar results to this study by using an organic compound as a source of nutrients in height growth of corn. However, Sousa and Guerra (2012), analyzing the initial growth of Physic nut with organic fertilization with bovine manure at dosages of 0, 50, 100 and 150 kg ha^{-1}, reported no significant effects for this variable.

Table 3. Summary of analysis of variance for the of number of leaves, in plant height (PH), stem diameter (SD)the shoot dry matter (SDW), photosynthesis (E), stomatal conductance (gs) and transpiration (A) corn plants fertigated with bovine biofertilizier, Fortaleza, 2011.

FV	Treatments	Blocks	Residue	Total	Mean	VC%
GL	4	4	16	20		
Variables		Mean Squares				
Number of leaves	3,93**	0,58ns	0,46	12,95	22,95	6,55
Plant height	1081,18**	175,2ns	88,24	5909,2	181,1	19,016
Stem diameter	10,92*	2,69ns	2,47	23,58	81,4	5,17
Shoot dry matter	18275,1**	43,79 ns	82,46	74221,5	137,97	6,58
Stomatal conductance	0,782**	0,023 ns	0,108	4,49	0,73	24,64
Photosynthesis	88,1**	0,97 ns	3,55	398	23,05	8,17
Transpiration	6,83ns	2,13 ns	6,55	112,4	11,91	21,49

FV= variation factor; GL = Degree of freedom; VC= variation coefficient; ** = significant at 1 % level by the test F, * = significant at 5 % level by the test F and ns = Not significant

Similar to what happen with the number of leaves and plant height, the variation of stem diameter (Figure 1C) with the increasing concentrations of bovine biofertilizer at 60 DAS was also a linear regression with a determining coefficient of 0.90. This data is consistent with the results found by Oliveira et al. (2011) with the application of biofertilizer under field conditions. Sousa et al. (2012), in greenhouse conditions, also found that increasing concentrations of bovine biofertilizer increased the corn stem diameter.

According to the data presented in Figure 1D, the model that best fit the shoot dry matter of the corn plants was linear, with a determining coefficient of 0.90, with the different concentrations of biofertilizer at 60 DAS. It can be concluded that the biofertilizer has influenced the processes of water supply and minerals from the root system to the shoots, as well as the synthesis and transportation of the growth regulators between the root system and the shoots (BRAGA, 2010; CAVALCANTE et al., 2007).

Data of this study were similar to those observed in corn with organic compost and fertilizer in a greenhouse (SARAIVA et al., 2010; SOUSA et al., 2012). Araújo et al. (2008), in field conditions, saw an increase in the leaf dry matter of the coffee plant under increasing concentrations of the super thin type of biofertilizer.

Net photosynthesis (Figure 2A) showed a linear variation with the increasing concentrations of bovine biofertilizer, with a determining coefficient of 0.81. The superiority of the C4 concentration (100%) of the bovine biofertilizer may be related to the significant presence of nitrogen in the plant's metabolism. Broadley et al. (2001) found that plants with nitrogen limitation had lower photosynthetic rate. Braga (2010) reported a quadratic model for photosynthesis in pine plants at 51 days after transplanting by applying different dilutions of bovine biofertilizer. According to this author, the level of dilution of bovine biofertilizer that stimulated the photosynthesis rate the most was 39.5%, achieving a 22.48 mmol m^{-2} s^{-1} on Physic nut plants. Erthal et al. (2010) reported that increasing rates of application of wastewater from cattle used in the form of fertigation increased the photosynthetic rate of Tifton 85 and oats.

Figure 2B shows that the variation in stomatal conductance in relation to increasing concentrations of bovine biofertilizer showed a quadratic model, with a determining coefficient of 0.86. Therefore, it was found that the stomatal conductance reached a maximum value (1.28 mmol m^{-2}s^{-1}) with a concentration of bovine biofertilizer of 60.37%. The superiority of stomatal conductance, in plants with bovine biofertilizer treatments compared to the control, highlights the positive action of this organic input. Similarly, Santos et al. (2010), evaluating the effects of doses of organic composts obtained from agroindustrial wastes, in gas exchanges in lettuce grown in a semi protected environment, found that plants fertilized with bovine manure had a higher stomatal conductance.

It is emphasized that this organic input has a high content of Na and the elevation dosages caused a reduction in osmotic potential of the ground hindering the absorption of water by plants and thus decreasing the stomatal conductance, as reported (VIANA et al., 2013). Similiar results were recorded in cowpea plants grown in a pot with beef and irrigated with saline water and biofertilizer (SILVA et al., 2011).

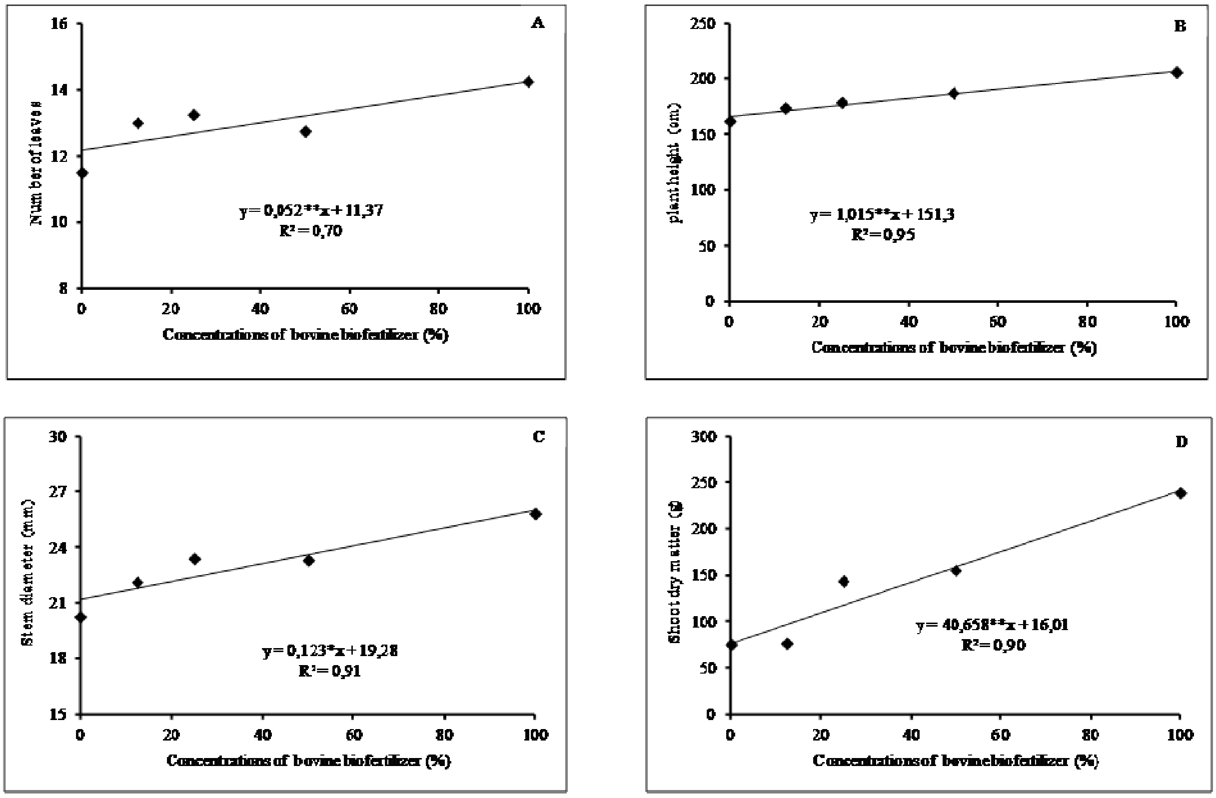

Figure 1. Number of leaves (A), plant height (B), stem diameter (C) and shoot dry matter (D) of corn plants under different concentrations of bovine biofertilizer.

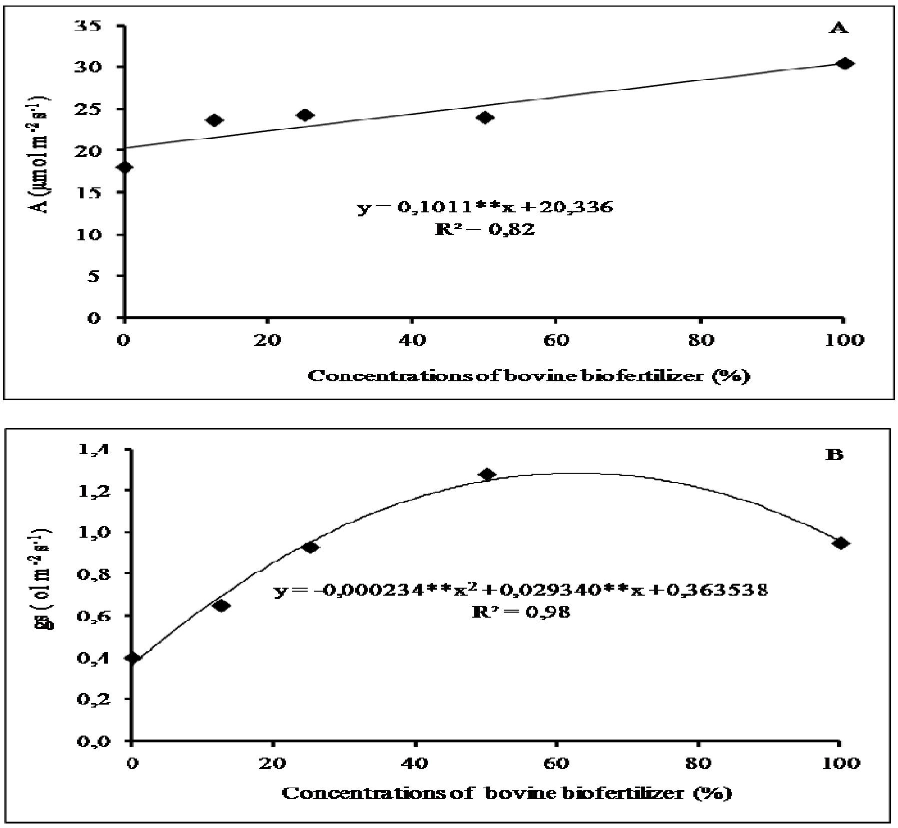

Figure 2. Values photosynthesis (A) e stomatal conductance (B), of corn plants under different concentrations of bovine biofertilizer.

Yield

Table 4 presents the results of variance analysis for the variable data of productivity of corn plants at 90 DAS. Based on the results, it can be verified that the concentrations of bovine biofertilizer provided significant effects at a the significance level of 1% and 5% by the F test for the variable weight of 1000 seeds (W1000S) and yield (Y), as for the weight of the ear husked and dehusked, no significant response was observed.

In this study, the reported results for the significant variables of the corn crop can be related to the greater supply of provinient nutrients from the biofertilizer in higher concentrations during the experimental period. It should be noted that, the nutritional value and biological materials of organic origin, for example, bovine biofertilizer, enhance the chemical and biological qualities of the soil (CAVALCANTE al., 2007) and promote a better development and yield for the crops (SILVA et al., 2011; DINIZ et al., 2011).

Table 4. Summary of analysis of variance for the of corn plants fertigated with bovine biofertilizier weight of the spike straw (WSS), weight of the spike without straw (WSWS), weight of 1000 seeds (W100S) and productivity (PROD), Fortaleza, 2011.

FV	Treatments	Blocks	Residue	Total	Mean	VC%
GL	4	4	16	24		
Variables	Mean Squares					
weight of the spike straw	7.029,92^{ns}	29.825,68^{ns}	20,527,21	386718,45	377,95	37,91
weight of the spike without straw	12.944,58^{ns}	23.352,30^{ns}	17171	29981,32	301,02	45,03
Weight of 100 seeds	1.030,00*	167,5^{ns}	2609,17	10587447	252	20,27
Yield	2.133.939,29**	209.132,74^{ns}	118690,97	35070	2262,57	15,22

FV= variation factor; GL = Degree of freedom; VC= variation coefficient; ** = significant at 1 % level by the test F, * = significant at 5 % level by the test F and ns = Not significant

For the variable weight of 1000 kernels, in the regression analysis (Figure 3A) a linear tendency can be observed, with R^2 = 0.98 with the concentrations of bovine biofertilizer. The highest yield of 1000 kernels with the highest concentration of bovine biofertilizer (100%) may be explained by the presence of potassium in the organic input. This essential nutrient is essential to the quality of fruits (RODRIGUES et al., 2008). Similar behavior was observed on this variable by Zanatta et al. (2007). These authors found a linear increase in the weight of 1000 kernels with increasing doses of nitrogen in corn crops.

In Figure 3B it can be verified that, that the treatments with bovine biofertilizer applications showed greater yield compared to the control treatment (without biofertilizer), generating a linear model with R^2 = 0.89. The yield obtained in the largest concentration of bovine biofertilizer was 3.506.29 kg ha^{-1}, these average yield values are above the general average in Brazil, 3.260 kg ha^{-1}, and below the United States, 4000 kg ha^{-1}, the largest producer in the world (FORNASIERI FILHO, 2007).

There was a productivity of 7.066 kg ha^{-1} of corn fertilized with bovine manure compared to control (1751 kg ha^{-1}) (REINA et al., 2010). Cancellier et al. (2011), using bovine manure as a source of nutrients, concluded that the organic input provided an average yield of 2.500 kg ha^{-1}. This variation is related to genetics planted cultivars and climate**.**

Santos et al. (2010), evaluating the residual effect of organic fertilizer on corn yield in an agroforestry system, reported a lower productivity than that of this study (2.001 kg ha^{-1}). Assessing the yield of the corn kernels subjected to organic fertilizer management (manure) in the semiarid region, Silva et al. (2011), had a productivity of 3,138 kg ha^{-1}.

The increase in productivity is linked to can influence the nutritional composition of bovine biofertilizer, which is applied in liquid form, provides greater displacement of nutrients required by plants (VIANA et al., 2013) reflecting directly on the nutritional status of plants. Larcher (2006) argues that the higher photosynthetic rates are achieved through fertilization.

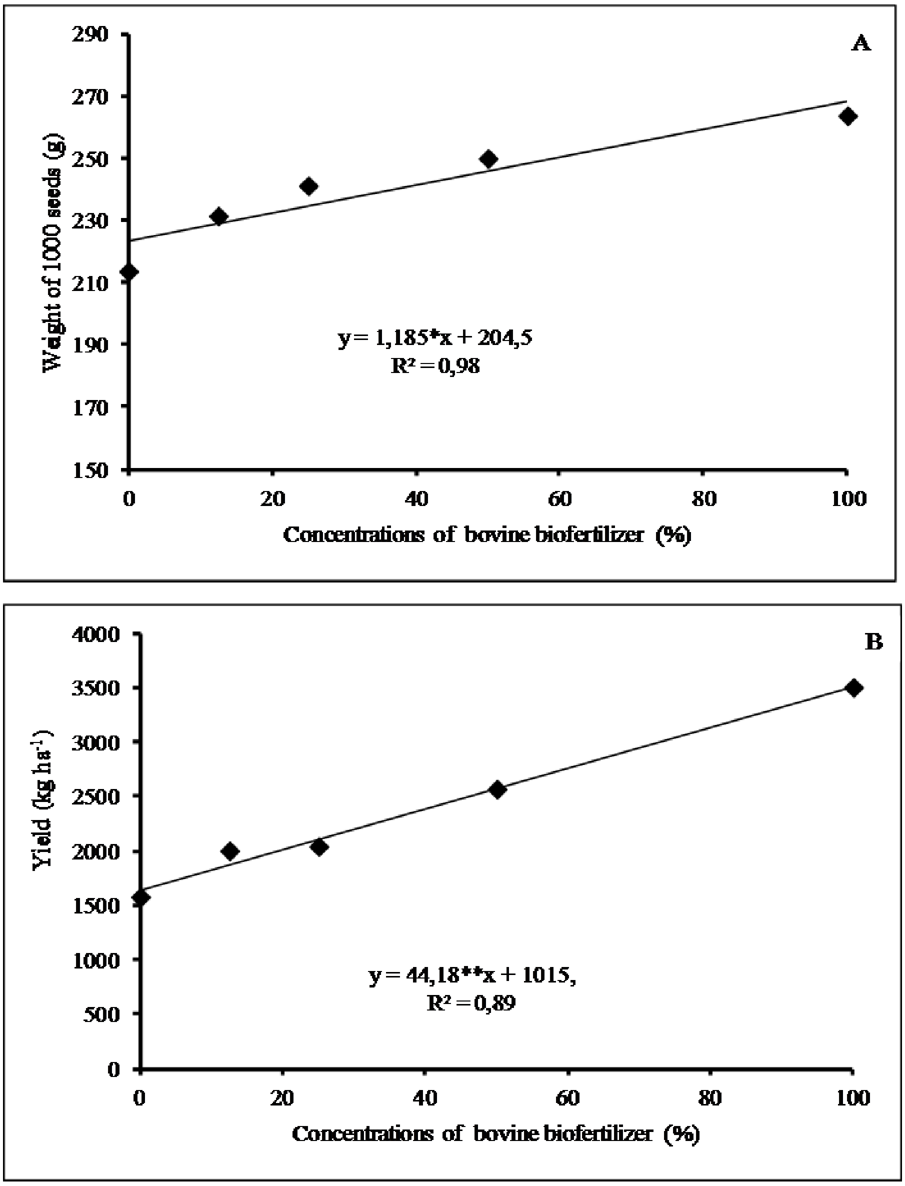

Figure 3. Weight of 1000 seeds (A) and yield (B) of corn plants under different concentrations of bovine biofertilizer.

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CONCLUSIONS

The biofertilizer was the most efficient considering the initial growth and gas exchange.

Also, the bovine biofertilizer treatments (as a whole) favored the increase in the weight of 1000 seeds and grain yield.

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