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Article

Growth and flowering of colored cotton cultivated in soils of distincts ESP and sheep manure

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Abstract

The inadequate management of irrigation has promoted the increase in the area of degraded soils through salinization and/or sodification, especially in irrigated perimeters of the northeastern semiarid, promoting environmental impacts and decrease in crop yield. In this manner, studies that aim to evaluate the tolerance of crops to salts, and/or techniques that minimize the deleterious effects of salt stress are highly viable. Based on this, the present study aimed to evaluate the influence of sheep manure doses over growth and flowering of the colored cotton cv. BRS Topázio, cultivated in soils with different exchangeable sodium percentages. A randomized block design was adopted, in a 5 x 4 factorial scheme, corresponding to the treatments of five exchangeable sodium percentages – ESP: 8.84, 12.55, 18.80, 28.80 and 38.80% and four sheep manure doses: 0, 5, 10 and 15% based on the volume of the soil, with 3 replications. At 90 days after sowing, it could be verified that the increment in the sheep manure doses added to the soil mitigated the negative effect of the ESP over the production of flower buds, beside stimulating plant growth, flower production and reducing the rate of flower abortion, independently of the ESP. The cotton cv. BRS Topázio is tolerant to soil ESP up to 38.8%, and anthesis is anticipated by the increase in exchangeable sodium.

Keywords: *Gossypiumhirsutum* L., sodicity, soil recovery, organic matter

Introduction

The colored cotton developed by Embrapa emerges as a viable alternative in the socioeconomic and environmental contexto in the Brazilian northeast, as its plume holds a value above the regular cotton, promoting an average water economy of 70% in the mesh finishing and eliminating the dyeing phase in the textile industry, which has released great amounts of residues in the environment (Cardoso et al., 2010).

The crop is well adapted to the edaphoclimatic conditions of the Brazilian northeast, possessing an excellent cultivation potential in this region (Embrapa, 2011). However, in irrigated perimeters, the cultivation of the species might turn restricted, due to the increase in the area of degraded soils by salinity and/ or sodicity, given the usage of saline waters in irrigation, the inadequate management of water and soil, and the insufficient drainage (Ribeiro, 2010).

The increase in the concentration of soluble salts in the soil promotes environmental impacts and affects the growth and production of the crops, in consequence of the osmotic effect, accumulation of toxic ions and nutritional disturbances (Apse & Blumwald, 2007). Conversely, the high concentration of

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exchangeable sodium in the soil causes physical problems, such as dispersion and migration of the colloids within the soil profile, with obstruction of pores and reduction in the movement of air and water, (Meloet al., 2008; Tavares Filho et al., 2012).

In saline soils, the recovery might be performed through the leaching of the soluble salts in the soil layer explored by the root system, but when the problem relates to the exchangeable sodium, the use of correctives is indispensable for replacing the effect of the dispersing ion (sodium) of the soil (Leite et al., 2007).

In this case, the use of organic matter has been tested, with good results, such as in the case of cow dung manure, which acts by releasing CO_2 and organic acids during decomposition, resulting in a higher aggregation of soil particles and decreasing the dispersion of soil clays, beside acting as source of calcium and magnesium, in detriment of the sodium (Miranda et al., 2011, Sá et al., 2015).

Pereira et al. (2012) verified a beneficial effect of the application of cow dung manure over growth and yield of the herbaceous colored cotton cv. BRS Rubi; furthermore, the mitigating action of the exchangeable sodium over the growth of the BRS Topázio variety cultivated in saline-sodic soil could be observed (Dias et al., 2016).

Sheep manure is a source of organic matter of easy obtainment for producers in the northeastern semiarid, promoting increases in the physical properties of the saline-sodic soil and, with that, demonstrating a potential in the reclamation of these soils (Miranda et al., 2011).

In this perspective, this research aimed to evaluate the influence of sheep manure doses over growth and flowering of the colored cotton cv. BRS Topázio cultivated in soils with different exchangeable sodium percentages.

Material and methods

The experiment was conducted in a greenhouse of the Centro de Ciências e Tecnologia Agroalimentar of the Federal University of Campina Grande – CCTA/UFCG, Campus of Pombal, PB, in the geographical coordinates 6°47'20'' S, 37°48'01'' W and average altitude of 194 m.

The treatments were arranged in a 5 x 4 factorial scheme, corresponding to the exchangeable sodium percentages in the soil (ESP): 8.84, 12.55, 18.80, 28.80 and 38.80% and the sheep manure doses (MD) of 0, 5, 10 and 15% based on volume. The treatments were randomized in blocks, with three replications, and experimental unit composed of one recipient containing one plant, spaced 0.6 m within lines and 0.3 m within plants.

The soils with distinct ESP were obtained through treatment with gypsum, according to Pizarro (1978), from a saline-sodic soil with initial ESP of 88.67% collected at a depth of 0-30 cm, in the São Gonçalo irrigated perimeter, located at 10 km from the municipality of Sousa, PB, whose physical and chemical characteristics (Table 1) were determined in the Laboratory of Soils and Plant Nutrition of the CCTA/UFCG.

Table 1. Physical and chemical characteristics of the soil utilized in the experiment, before gypsum application for the formulation of the treatments.

Density	Total Porosity	Sand	Silt	Clay	Exchange Complex				ESP	pH_{se}	EC_{se}
					Ca^{2+}	Mg^{2+}	Na^+	K^+			
kg dm^{-3}	m^3 m^{-3}	............g kg^{-1}............			..............$cmol_c$ kg^{-1}...............				%	-	dS m^{-1}
1.38	0.48	470	310	220	0.50	1.00	24.41	1.62	88.67	9.78	4.7

ESP – Exchangeable sodium percentage; pHse – pH of the saturation extract, ECse – Electrical conductivity of the saturation extract at 25 °C.

Following that, the treated and air-dried soil was pounded and passed through a 2 mm mesh sieve, when samples were removed and analyzed as to the exchangeable sodium percentages (ESP), obtaining the values of the distinct treatments.

The doses of decomposed sheep manure, whose chemical characteristic (Table 2) were determined in the Laboratory of Soils and Plant Nutrition of the CCTA/UFCG, doses of gypsum were incorporated to the soil with distinct ESP at the filling of the recipients, being mixed with the upper layer of the soil.

Table 2. Chemical characteristic of the sheep manure utilized in the experiment.

pH	EC 1:5	P	O.M	N	K	Na	Ca	Mg
1:2.5	dS m^{-1}	mg dm^{-3}	g dm^{-3}	%	......................$cmol_c$ dm^{-3}....................			
7.79	0.31	39	47	1.96	0.83	0.68	3.2	5.1

EC – Electrical conductivity at 25 °C; O.M - Organic matter.

Containers (lysimeters) with capacity of 12 L were utilized in the experiment, filled with 10 dm^3 of soil of the respective treatment, presenting in the base n° zero gravel layer (1 kg) and a sand layer. Each lysimeter presented two holes in its base, allowing drainage, and under each hole a microtube (1 cm diameter) connecting its base to a plastic bottle (2 L capacity), where the monitoring of the drained volume and the estimative of water consumption by the crop were performed.

The utilized cotton cultivar was the BRS Topázio, which possesses a herbaceous size, clear-brown fiber, and stands out by its elevated fiber percentage (43.5%), high uniformity (85.2%) and resistance (31.9 gf/tex), compared to the white fiber cultivars, besides being well adapted to the edaphoclimatic conditions of the semiarid region of the Brazilian northeast (Embrapa, 2011).

Embrapa Algodão/Campina Grande – PB donated the utilized seeds. The sowing was performed on 01 December 2015, whose soil material was initially placed in field capacity, placing five seeds per lysimeter at a depth of 2 cm, and equidistantly distributed. At 30 days after sowing (DAS) the pruning was performed, allowing one plant per recipient, the more vigorous.

The phosphate fertilization was performed in base-dressing (300 mg of P kg^{-1} of soil), utilizing the single superphosphate, and the potassium fertilization (150 mg of K kg^{-1} of soil) was performed of potassium chloride, according to the recommendations of Novais et al. (1991), by applying 1/3 in base-dressing and the remaining (2/3) in fertigation, at eight-day intervals, from 25 DAS.

The irrigations were daily performed at the end of the afternoon with water from the local supply, with electrical conductivity of 0.3 dS m^{-1}, and determined based on the water balance of the soil, estimated as the difference between the applied volume and the drained volume, adding as leaching fraction of 10% more water.

Plant growth was evaluated at 90 DAS, through the height (PH), stem diameter (SD), number of leaves (NL), leaf area (LA), absolute growth rate for plant height (AGRph) and stem diameter (AGRsd). Flowering was evaluated through the number of flower buds (NFB), days for the opening of flower bud (DOFB), number of flowers (NFLOW) and rate of flower abortion (ROFA).

Plant height was determined by measuring the distance between the base of the stem and the insertion of the apical meristem. The SD was measured at 5 cm from the stem base of the plants. The NL was quantified by counting only the leaves that possessed a minimum of 50% of photosynthetically active area, and minimum length of 2 cm. The same criteria were adopted for the measurement of the LA, obtained through the Eq. 1 (Grimes& Carter, 1969):

$$Y = 0.4322\, x^{2.3002} \quad \text{(Eq. 1)}$$

In which: Y= total leaf area (cm^2); x= length of the main leaf vein (cm).

The AGRph and AGRsd were determined according to the Eq. 2 and Eq. 3, considering the growth interval between 25 and 90 DAS.

$$AGRph = \frac{(PH_2 - PH_1)}{(t_2 - t_1)} \quad \text{(Eq. 2)}$$

$$AGRsd = \frac{(SD_2 - SD_1)}{(t_2 - t_1)} \quad \text{(Eq. 3)}$$

In which: AGRph = absolute growth rate for plant height (cm day^{-1}); AGRsd = absolute growth rate for stem diameter (mm day^{-1}); PH_1 = plant height (cm) in the time t_1; PH_2 = plant height (cm) in the time t_2; SD_1 = stem diameter (mm) in the time t_1; SD_2 = stem diameter (mm) in the time t_2;

The NFB and the NFLOW were determined through counting after the emergence of the reproductive structure. The interval in days was considered in the determination of the DOFB, from the sowing until the moment in which all petals of each flower opened entirely. After the beginning of the flowering, every three days, the counting of the number of flowers and fruits per plant was performed, and at the experimental ending, the

ROFA was measured as the difference between these variables.

The obtained data were evaluated through variance analysis by the F test, and in the cases of significance ($p<0.05$), polynomial regression analysis was performed, utilizing the statistical software SISVAR (Ferreira, 2011).

Results and Discussion

It could be found that there was no significant effect ($p>0.05$) of the ESP levels of the soil over PH, SD, NL, LA, AGRph and AGRsd of the colored cotton plants in the period of 90 DAS. However, a significant effect was observed ($p<0.01$) of the sheep manure doses over the growth variables. The interaction between the factors ESP x DE was not significant ($p>0.05$) for these studied variables (Table 3).

The fact that the growth variables of the cotton plants at 90 DAS were not affected by the ESP levels of the soil, varying from 8.84 to 38.80% (Table 3), might be related to tolerance mechanisms of the cultivar to sodicity, since, according to Willadino & Camara (2010) glycophytic plants may present abilities for controlling sodium transportation, through the absorption selectivity of the root cell; transport preference of K^+ in the xylem in relation to Na^+; xylem salt removal in the upper part of roots, stem, petiole or leaf sheaths, or even the retranslocation of Na^+ in the phloem; thus assuring the absence of translocation for tissues of the shoot part in growth process; that is, it is inferred that some of these mechanisms might have been developed by cv. BRS Topázio, seen that the growth was not affected by the high sodicity of the soils.

Table 3. Variance analysis summary for plant height (PH), stem diameter (SD), number of leaves (NL) and leaf area (LA) at 90 DAS, and absolute growth rate for plant height (AGRph) and stem diameter (AGRsd) of colored fiber cotton cv. BRS Topázio cultivated in soil with distinct ESP, under doses of sheep manure in the interval from 25 to 90 DAS.

Source of variation	Mean Square					
	PH	SD	NL	LA[1]	AGRph	AGRsd
ESP	108.650^{ns}	0.387^{ns}	2.250^{ns}	48347.84^{ns}	0.027^{ns}	9.8E-05^{ns}
Doseges of manure (DM)	2268.133**	14.528**	286.328**	2430386.41**	0.506**	0.003**
Linear regression	6366.413**	42.624**	850.083**	6948432.30**	1.415**	0.010**
Quadratic regression	299.267*	0.908^{ns}	4.817^{ns}	239627.86^{ns}	0.072*	3.0E-04^{ns}
Interaction ESP*DM	61.9388^{ns}	0.649^{ns}	11.216^{ns}	74482.41^{ns}	0.015^{ns}	1.2E-04^{ns}
BLOCK	400.550*	0.455^{ns}	10.550^{ns}	3617.33^{ns}	0.080**	2.2E-04^{ns}
CV (%)	14.26	11.58	17.73	13.92	17.43	16.87

ns, **, * respectively not significant, significant at $p < 0.01$ and $p < 0.05$. 1statistical analysis performed after the transformation of the data in $\sqrt{X}$.

Costa et al. (2016) and Dias et al. (2016) also verified cotton BRS Topázio tolerance to sodicity, in which ESP levels of up to 30% did not compromise plant growth in height, diameter and number of leaves at 44 DAS. In the same manner, Almeida et al. (2015) verified that ESP of up to 48% did not influence the length and diameter of branches, stem diameter and number of leaves of cotton cv. BRS Topázio in the second production cycle.

Plant growth in PH, SD, NL, LA, AGRph and AGRsd in the colored cotton cultivated in soils of distinct ESP was stimulated ($p<0,01$) by the application of sheep manure, with an increasing linear effect being observed, occurring gains of 20.48, 14.05, 27.59, 65.36, 30.02 and 22.95% for every increase of 5% in the doses of sheep manure over the respective variables (Figure 1). The incorporation of sheep manure in the soil allows the providing of nutrients and increases the contents of organic matter, which serves as a linking agent within the components of the soil, positively interfering in its physical attributes, increasing hydraulic conductivity, infiltration and water retention (Miranda et al., 2011; Severino et al., 2006; Lima et al., 2007), as well as promoting improvements in the aeration and in the follow up of the root system, allowing a greater plant growth (Pereira, et al., 2012; Costa et al., 2016; Dias et al., 2016).

It was observed that increments in the application of bovine manure up to the doses of 15%, based on volume, favor the growth in height and stem diameter of colored cotton BRS Topázio (Almeida et al., 2015; Costa et al., 2016; Dias et al., 2016); a similar effect was observed over the cultivar BRS Rubi, through the application of the bovine manure dose of up to 40 t ha^{-1} (Araújo et al., 2011; Pereira, et al., 2012).

It is observed, in Table 4, that there was significant interaction ($p<0.05$) between the ESP of the soil and the doses of sheep manure for the number of flower buds. Likewise, it is verified that an isolated significant effect ($p<0.01$) of the ESP of the soil occurred over the number of days for the opening of the flower bud (DOFB), and of the factor sheep manure doses over the number of flowers - NFLOW ($p<0.05$) and for the rate of flower abortion ($p<0.01$).

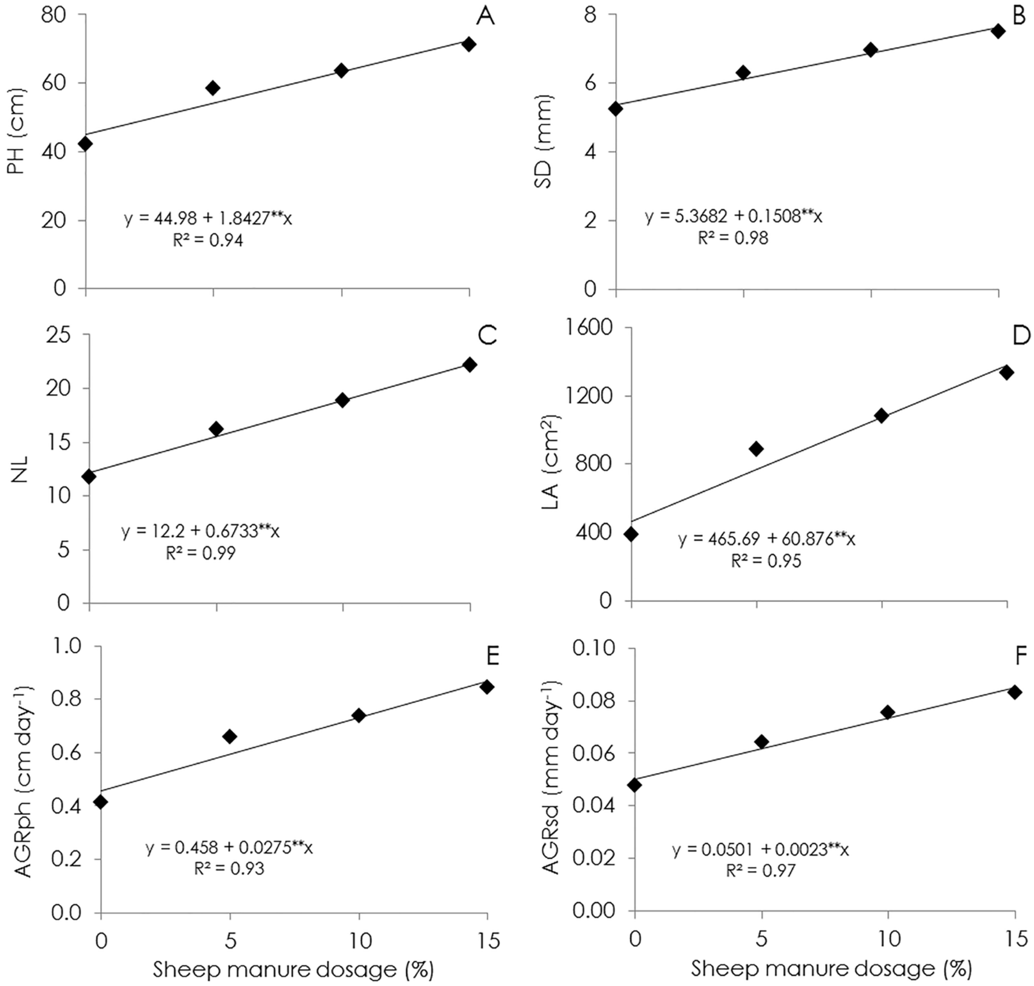

Figure 1. Plant height – PH (A), stem diameter – SD (C), number of leaves – NL (C), leaf area – LA (D), absolute growth rate for plant height – AGRph (E) absolute growth rate for stem diameter – AGRsd (F) of colored fiber cotton cv. BRS Topázio in function of sheep manure doses at 90 days after sowing – DAS, cultivated in soils with exchangeable sodium percentage varying from 8.84 to 38.80%.

Table 4. Variance analysis summary for number of flower buds (NFB), days for opening of flower bud (DOFB) number of flowers (NFLOW) and rate of flower abortion (ROFA) of the colored fiber cotton cv. BRS Topázio cultivated in soil of distinct ESP, under sheep manure doses at 90 days after sowing - DAS.

Source of variation	Mean Square			
	NFB[1]	DOFB	NFLOW[1]	ROFA[1]
ESP	0.792^{ns}	475.767**	3.642^{ns}	769.951^{ns}
Linear regression	-	1840.833**	-	-
Quadratic regression	-	0.214^{ns}	-	-
Doses of manure (DM)	79.311**	108.978^{ns}	41.350**	1361.715*
Linear regression	225.33**	-	111.630**	7.840*
Quadratic regression	9.600^{ns}	-	7.350^{ns}	16.537**
Interaction ESP*DM	7.769*	77.255^{ns}	4.142^{ns}	410.073^{ns}
BLOCK	0.867	48.717^{ns}	2.869	403.180^{ns}
CV (%)	11.27	13.46	17.32	21.02

ns, **, * respectively not significant, significant at $p < 0.01$ and $p < 0.05$. 1statistical analysis performed after the transformation of the data in √X.

In the development of the sheep manure doses within each soil ESP level, a better adequacy of the NFB data is verified in equation of increasing linear regression, indicating that the increase in the sheep manure dose mitigates the negative effect of the exchangeable sodium in the soil over flower bud production, occurring increments in the NFB of 41.86, 70.59, 63.96, 15.24 and 21.2% for the addition of every 5% in the dose of sheep manure, over the plants cultivated in soils with ESP 8.84, 12.55, 18.80, 28.80 and 38.80%, respectively (Figure 2A). Still in Figure 2A, it is seen that the manure doses were beneficial to the plants subjected to the three lowest ESP levels, possibly due to the manure ability in promoting a greater aggregation of soil particles, decreasing the dispersion of clays and reducing the toxic effect of the Na^+ in these ESP levels.

The application of sheep manure in saline-sodic soils decreases soil compaction, increases the volume of pores and promotes the input of potassium, calcium and magnesium, reducing the effect of the exchangeable sodium and improving the physical properties of the soil (Miranda et al., 2011), what might reflect positively over the quantity of bud flowers in the herbaceous cotton, favored by the adequate supply of nutrients and water in the soil, as observed by Arruda et al. (2002).

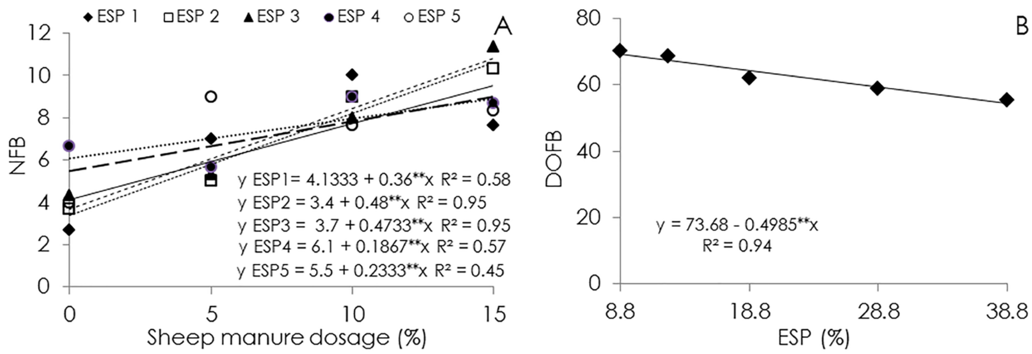

Figure 2. Number of flower bud – NFB (A) of colored fiber cotton cv. BRS Topázio cultivated in soil with distinct exchangeable sodium percentages (ESP) in function of sheep manure doses, and number of days for the opening of flower bud - DOFB (B) in function of the ESP under sheep manure doses varying from 0 to 15% at 90 days after sowing – DAS.

It is observed that there was a linear decrease of the number of days for the opening of flower bud in function of the increase in the soil ESP, occurring decreases of 21.55% (14.93 days) in the soil of highest ESP (38.80%) compared with the plants cultivated in lower ESP (Figure 2B). In this manner, it might be deduced that the increase in the soil ESP levels precociously stimulated the opening of the flower bud. It is inferred that it might have been caused by the stress due to the exchangeable sodium effect, with this anticipation of the opening of flower bud being an alternative for precocious seed production, thus ensuring the perpetuation of the species under stress conditions. Arruda et al. (2002) recognize that cotton plants subjected to abiotic stresses present precocious aging symptoms by the increase of ethylene and abscisic acid, what, in fact, might anticipate the opening of the flower bud. Nevertheless, the stress effect due to the excess of exchangeable sodium in the soil over anthesis in the colored cotton plant is little known, and it should be better investigated through further research.

For the number of flowers, a better adjustment of the data to the increasing linear model is verified through the increment in the sheep manure dose, occurring gains of 52.58% for every increase of 5% in manure dose (Figure 3A). According to Silva et al. (2011), the formation of flowers in the cotton plant is intimately related to environmental factors, such as humidity and soil fertility, occurring the increase in this reproductive structure in the species when satisfactory conditions of these parameters are present (Arruda et al., 2002). Miranda et al. (2011) observed that the increase in sheep manure dose provided improvement of these properties in a saline-sodic soil.

It is verified that the rate of flower abortion was reduced, from 56.68% in the plants which did not receive the manure, to 36.22% in the plants

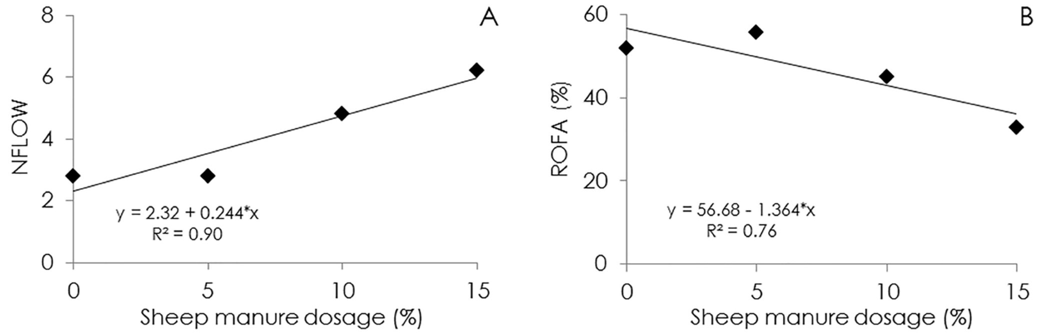

Figure 3. Number of flowers – NFLOW (A) and rate of flower abortion – ROFA (B) of colored fiber cotton cv. BRS in function of sheep manure doses at 90 days after sowing - DAS, cultivated in soils with distinct exchangeable sodium percentages.

fertilized with the highest sheep manure dose (15% dose). This favorable result reflected a linear reduction of 12% in the ROFA for every increase of 5% in the dose of sheep manure in the soil, that is, a decrease of 36.10% in the plants fertilized with the dose of 15% of manure, compared to the plans which did not receive organic matter (Figure 3B).

Oosterhuis (1992) reported that the abscission rate of reproductive structures in cotton within 57 and 60% is considered normal, what might be even accentuated due to nutrient and water deficiency. However, it is found in the present work (Figure 3B) that the increase in the sheep manure dose reduced the rate of flower abortion to a level well below the acceptable value, possibly because this organic fertilizer provides favorable edaphic conditions for the higher retention of flowers, such as nutrients availability, permeability and storing of water in the soil. Arruda et al. (1992) affirm that in management systems of soils with water and nutrient deficiency, the fall of cotton reproductive structures is accentuated, whereas in satisfactory conditions of these factors, the plant normally presents a higher retention of these structures, resulting in a lower rate of abortion.

Conclusions

The increment in sheep manure doses in the soil mitigates the negative ESP effect over the production of flower bud in the colored cotton cv. BRS Topázio;

Increases in sheep manure doses stimulate plant growth, flower production, and reduces the rate of abortion of these reproductive organs, independently of the ESP;

The growth of the cotton cv. BRS Topázio is tolerant to the soil ESP of up to 38.8%, while anthesis is anticipated by the increase in the exchangeable sodium.

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