Revista Ciência Agronômica
ISSN: 0045-6888
ISSN: 1806-6690
Universidade Federal do Ceará

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Revista Ciência Agronômica, vol. 49, no. 1, January-March, 2018, pp. 130-140
Universidade Federal do Ceará

DOI: 10.5935/1806-6690.20180015

Revista Ciência Agronômica, v. 49, n. 1, p. 130-140, jan-mar, 2018
Centro de Ciências Agrárias - Universidade Federal do Ceará, Fortaleza, CE
www.ccarevista.ufc.br

Artigo Científico
ISSN 1806-6690

Silicon as an attenuator of salt stress in *Brachiaria brizantha* 'MG5'[1]

Silício como atenuante do estresse salino em *Brachiaria brizantha* cv. MG5

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ABSTRACT - The aim of this study was to evaluate the effect of salt stress and silicon fertiliser on growth and nutritional value in *Brachiaria brizantha* 'MG5'. The experimental design was completely randomised in a 4 x 5 x 3 factorial scheme with four replications; the treatments consisted of four concentrations of sodium chloride (0, 20, 40 and 60 mmol L^{-1}), with five concentrations of silicon (0, 1, 2, 3 and 4 mmol L^{-1}) in the nutrient solution, and three cutting periods (30, 60 and 90 days). The concentration of 4 mmol L^{-1} silicon minimised the detrimental effects of the sodium chloride on regrowth. However, the levels of silicon application were not sufficient to reduce the harmful effects of the sodium chloride on nutritional value or on dry-matter production in *Brachiaria brizantha* 'MG5'.

Key words: Silicon fertiliser. Salinity. Pasture quality.

RESUMO - Objetivou-se avaliar o efeito do estresse salino e da adubação silicatada no crescimento e valor nutritivo da *Brachiaria brizantha* cv. MG5. O experimento foi em delineamento inteiramente casualizado, sob o esquema fatorial 4 x 5 x 3, com quatro repetições, onde os tratamentos foram quatro concentrações de cloreto de sódio (0; 20; 40 e 60 mmol L^{-1}), com cinco concentrações de silício (0; 1; 2; 3 e 4 mmol L^{-1}) na solução nutritiva e três épocas de corte (30; 60 e 90 dias). A concentração de 4 mmol L^{-1} de silício minimizou os efeitos deletérios do cloreto de sódio na rebrota. Entretanto, as aplicações dos níveis de silício não foram suficientes para atenuar os efeitos prejudiciais do cloreto de sódio no valor nutritivo e na produção de massa seca da *Brachiaria brizantha* cv. MG5.

Palavras-chave: Adubação silicatada. Salinidade. Qualidade da pastagem.

DOI: 10.5935/1806-6690.20180015
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Recebido para publicação em 15/02/2016; aprovado em 08/02/2017
[1]Parte da Dissertação do primeiro autor, apresentado ao Programa de Pós-graduação em Ciência Animal e Pastagem, Universidade Federal Rural de Pernambuco/UFRPE. Pesquisa apoiada pela CAPES e FACEPE
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INTRODUCTION

The term salinity refers to the existence of soluble salts in the soil that can significantly impair plant development (YADAV *et al*., 2011). Salinity therefore, is an abiotic stress that interferes with the growth of most plant species, mainly due to the toxicity caused by the excessive absorption of such salts as the sodium (Na^+) and chloride (Cl^-) ions (SHAHZAD *et al*., 2012), which results in nutritional imbalances in the plants (AHMAD *et al*., 2013; RAHIMI *et al*., 2012).

An alternative to reduce the damaging effects of salts is the use of silicon (Si) with the fertiliser, since the addition of this element increases salt tolerance in Poaceae (PARVEEN; ASHRAF, 2010). Although Si is not considered essential to plants, it is a beneficial element that reduces the impact of stress-inducing agents (MA; YAMAJI, 2015). An increase in Si availability results in an increase in growth, as this element can act indirectly on various photosynthetic and biochemical aspects of the plants, increasing the levels of chlorophyll in leaf tissue, altering plant architecture, avoiding excessive self-shading, delaying senescence and protecting plants when subjected to any type of stress (ABDALLA, 2011).

Recent studies have shown the beneficial effects of Si on the growth of many plant species (*Saccharum officinarum*, *Sorghum bicolor* and *Zea mays*) subjected to conditions of salt stress (ASHRAF *et al*., 2010; ROHANIPOOR *et al*., 2013; YIN *et al*., 2013). However, considering grasses used for animal feed, the amount of Si can compromise forage quality (MELO; MONTEIRO; BONA, 2010), since the deposition of silica on the cell wall increases the abrasiveness of the leaves, thereby reducing their acceptability to grazing animals.

In this context, forage quality becomes an important factor to be considered in obtaining good animal performance. In Brazil, grasses of the genus *Brachiaria* spp. occupy approximately 85% of the area of cultivated pasture. Among the species of this genus, one has been gaining prominence on the domestic scene, *Brachiaria brizantha* ‘MG5’; with yields of 10 to 18 tons of dry matter ha^{-1} $year^{-1}$ and showing rapid regrowth and late flowering, its use is viable in cattle production (CARVALHO *et al*., 2014).

Studies on forage plants under stress conditions, as well as the beneficial effects of silicon on the plants, are scarce. The aim of this study was to evaluate the influence of salt stress and silicate fertiliser on the growth and chemical and bromatological composition of *B. brizantha* ‘MG5’.

MATERIAL AND METHODS

The experiment was carried out in a greenhouse, with the analysis carried out at the Animal Nutrition Laboratory (LANA) and the Garanhuns Laboratory Centre (CENLAG), both located in the Garanhuns Academic Unit of the Federal Rural University of the State of Pernambuco (UAG/UFRPE).

The experiment was conducted in a completely randomised design in a 4 x 5 x 3 factorial scheme, with four concentrations of sodium chloride (NaCl) (0, 20, 40 and 60 mmol L^{-1}), equivalent to an electrical conductivity of 0, 3.9, 7.5 and 10.9 dS m^{-1} respectively; five concentrations of silicon (Si) (0, 1, 2, 3 and 4 mmol L^{-1}) in the nutrient solution; with three cutting periods, one every 30 days (COSTA *et al*., 2007); and four replications, where an experimental lot was represented by one pot containing one plant.

The seeds of *B. brizantha* ‘MG5’ were distributed in trays containing washed sand moistened with deionised water. After emitting the first leaf, the seedlings were transplanted to trays of 10.0 L containing Hoagland and Arnon (1950) nutrient solution under aeration, at an ionic strength of 25%, increasing by 25% ionic strength until reaching 75%. After 15 days adaptation, the plants were permanently transferred to the pots (height: 18 cm, diameters: 18 and 16 cm, and volume: 3.5 L), containing a nutrient solution at 100% ionic strength, with the respective treatments under aeration by compressor.

The doses of Si were applied via a 1.0 M solution of potassium silicate (commercial solution of K_2SiO_3 with 171 g Si L^{-1}; 210 g K_2O L^{-1}; pH = 12; density = 1.4 g cm^{-3}). The doses of K^+ were adjusted by a reduction in the dose of KNO_3, and the doses of N by the addition of HNO_3. When necessary, the volume of the solution was topped up, and the pH adjusted to 5.5 by the addition of 0.5 mol H_2SO_4 L^{-1} and 0.5 mol KOH L^{-1}. The Electrical Conductivity (EC) of the solution in each pot was also monitored every two days. When the EC of the plant solutions fell to 40% of the initial solution, the solutions were changed.

For growth variables, plant height and the number of tillers were evaluated. The number of inflorescences and senescent leaves were also quantified. These variables were quantified before each cut. The cut was then made at a height of 15 cm from the base of the plant to obtain the aerial part (TAMELE, 2009).

The aerial part from each cut was dried in a forced air circulation oven at 65 ºC to determine the shoot dry matter production (g pot^{-1}), and then ground in a Wiley mill with a 1.0 mm mesh sieve. From this fraction, aliquots were taken to determine the levels of shoot dry matter (DM), organic matter (OM), mineral matter (MM), crude protein (CP), neutral detergent fibre (NDF) and acid detergent fibre (ADF) (AOAC, 1990). The neutral detergent insoluble protein (NDIP) and acid detergent insoluble protein (ADIP) were determined as per Detmann *et al.* (2012), and the Si content as per Bezerra Neto and Barreto (2011).

The data were submitted to analysis of variance and then fitted to the multivariate mathematical model (response surface) as a function of the Si and NaCl concentrations in the nutrient solution, with the aid of the R software (R CORE TEAM, 2014). In order to compare the different collections, identity-testing of the mathematical models was carried out when these were similar. A significance level of 5% ($P<0.05$) was adopted. The graphics were constructed using the SigmaPlot 11.0 software (SYSTAT SOFTWARE INC., 2008).

RESULTS AND DISCUSSION

First Cut

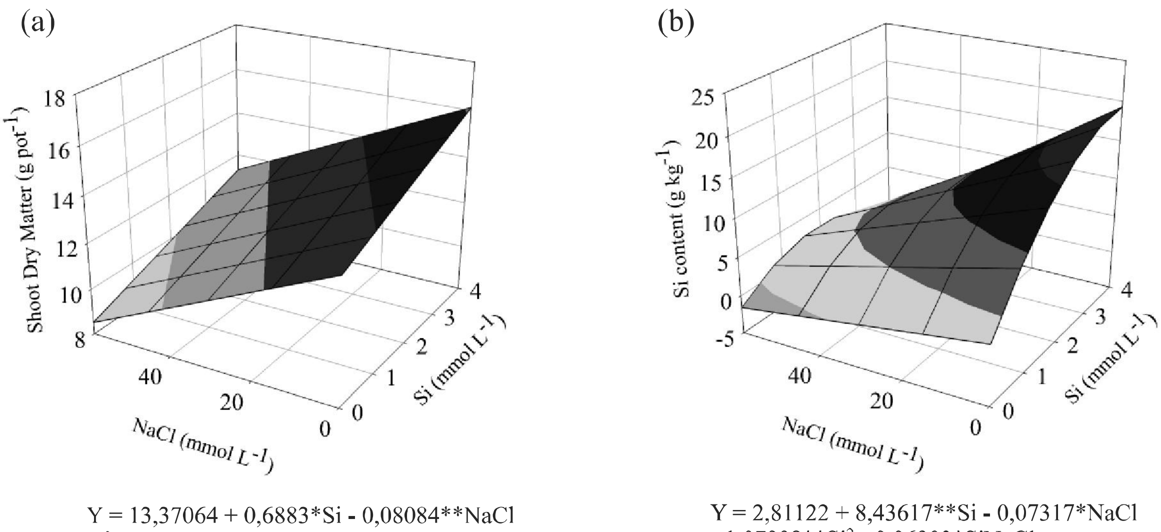
Shoot dry weight (SDW) reduced linearly as a function of the NaCl concentration in the medium (8.53 g.pot^{-1} at 60 mmol L^{-1} NaCl) (Figure 1a). With the increasing Si in the solution, an increase was seen in SDW to 11.27 g.pot^{-1} at 60 mmol L^{-1} NaCl and 4 mmol L^{-1} Si, however, the Si concentrations were not enough to minimise the damaging effects of the NaCl or improve vegetative growth in the forage.

An excess of salts in plants alters the rate of photosynthesis, impairing growth (BALAKHNINA; BORKOWSKA, 2013). The decrease in photosynthetic rate is due to several factors: a) dehydration of the cell membranes that reduce their permeability to CO_2; b) salt toxicity; c) reduction in CO_2 assimilation; and d) greater salinity-induced senescence (ROHANIPOOR *et al*., 2013).

The levels of Si in the plant tissue reduced as a function of the NaCl concentration in the solution (Figure 1b). There was a quadratic effect as a function of the Si concentration in the medium, with the highest values seen with 3.90, 3.25, 2.61 and 1.95 mmol L^{-1} Si at concentrations of 0, 20, 40 and 60 mmol L^{-1} NaCl in the solution respectively (Figure 1b).

The reduction in Si absorption can be explained by the decrease in plant transpiration when under stress (ASHRAF; HARRIS, 2013). Less transpiration in the plants reduces metabolic activity and the energy available for nutrient absorption (TAIZ; ZEIGER, 2013). As Si absorption is active, and requires more energy (MA; YAMAJI, 2015), there is consequently less absorption under stress.

Figure 1 - Shoot dry matter production (a) and silicon content (b) in the aerial part of *Brachiaria brizantha* 'MG5' under Si and NaCl concentrations in nutrient solution for the first cut



$Y = 13{,}37064 + 0{,}6883^{*}Si - 0{,}08084^{**}NaCl$
$R^2 = 0{,}69$

$Y = 2{,}81122 + 8{,}43617^{**}Si - 0{,}07317^{*}NaCl - 1{,}07998^{**}Si^2 - 0{,}06903^{*}SiNaCl$
$R^2 = 1{,}00$

*and **Significant by F-test at 5% and 1% probability respectively

The number of tillers (NT) reduced linearly as the NaCl concentrations in the medium increased. The lowest value for NT was 12 plant^{-1} at the concentration of 60 mmol L^{-1} NaCl, with the greatest value of 16 plant^{-1} when grown with no stress (Table 1). There was an increase in the number of floral tassels (NFT) and number of senescent leaves (NSL) with the addition of the NaCl concentrations (Table 1).

One of the tolerance mechanisms to salt stress in plants is stomatal closure, to reduce the accumulation of salts in the plant tissue. There is a decrease in gas exchange and a consequent reduction in CO_2 assimilation through photosynthesis, with a negative effect on growth (ASHRAF; HARRIS, 2013; BALAKHNINA; BORKOWSKA, 2013). In this way, the toxicity of the ions reduced the formation of new tillers and the production of SDW, accelerating leaf senescence (AHMAD *et al*., 2013), and leading to shortening of the development cycle of the plant.

With the acceleration of senescence and the phenological cycle, photoassimilates and leaf nutrients were mobilised for seed production and lignification of supporting tissue such as stalks (TAIZ; ZEIGER, 2013), which had a negative effect on the growth variables.

The Si and NaCl concentrations in the solution did not alter plant height in the first cut, where the average value was 85.18 cm; whereas for DM content, an inverse quadratic effect was seen with the Si concentration in the medium (Table 1). The lowest value for DM (291.40 g kg^{-1} NM) was obtained with 2.65 mmol L^{-1} Si in the solution. With the increase in Si concentration there was an increase in the water content of the aerial part of the plants. The Si absorbed by plants is accumulated in bulliform cells (MELO; MONTEIRO; BONA, 2010), and its accumulation and precipitation in the leaf reduce water loss in the plants by inhibiting the rate of transpiration (LIANG *et al*., 2015).

The levels of OM and MM varied as a function of NaCl concentrations in the solution with a quadratic fit (Table 1). The highest value for OM (909.60 g kg^{-1} DM) and lowest value for MM (90.40 g kg^{-1} DM) were obtained with 21 mmol L^{-1} NaCl in the nutrient solution. Plants under stress reduce ion absorption (TAIZ; ZEIGER, 2013).

The reduction in MM up to 21 mmol L^{-1} NaCl in the solution can be attributed to less ion absorption. However, there was an increase in MM in plants grown at concentrations greater than 21 mmol L^{-1} NaCl in the medium. This increase is associated with the effect of the ion concentration on plant tissue, since there was a reduction in plant growth (Figure 1a), demonstrating the effects of salt stress on *B. brizantha* 'MG5'.

The reduction in OM content with the increase in NaCl concentration can be explained by the accumulation of salts in the plant tissue (SHAHZAD *et al*., 2012; YADAV *et al*., 2011), which impaired plant growth.

With the increase in NaCl and Si concentrations in the solution, a reduction was seen in the values for CP. The minimum value was 100.18 g kg^{-1} DM with 4 mmol L^{-1} Si and 60 mmol L^{-1} NaCl (Figure 2a). The reduction in CP can be explained by the greater increase in senescence (Table 1) of the plants under salinity, thereby reducing the nutrient value of the forage.

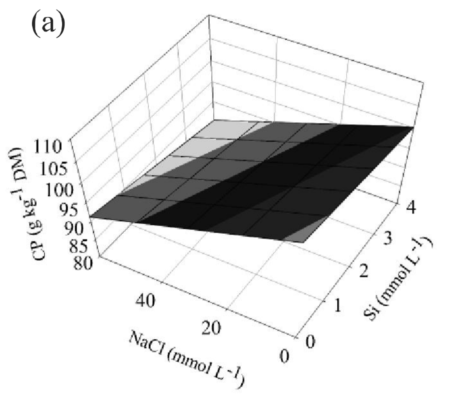
Table 1 - Growth, and chemical and bromatological composition (g.kg^{-1} DM) in *Brachiaria brizantha* 'MG5' for isolated concentrations of NaCl or Si in the nutrient solution

Variable[a]	Equation	R^2
NT	Y = 15.7636 - 0.0604*NaCl	0.70
NFT	Y = 1.13327 + 0.02765*NaCl	0.91
NSL	Y = 11.9117 + 0.3748**NaCl - 0.004983**NaCl^2	0.99
DM (g/kg NM)	Y = 314.824 - 17.673*Si + 3.335*Si^2	0.74
OM	Y = 901.3593 + 0.7854**NaCl - 0.0187**NaCl^2	0.94
MM	Y = 98.6407 - 0.7854**NaCl + 0.0187**NaCl^2	0.94
ADIP	Y = 11.686 - 0.1383NaCl + 0.002114**NaCl^2	1.00

[a] NP, number of tillers; NFT, number of floral tassels; NSL, number of senescent leaves; DM, dry matter; OM, organic matter; MM, mineral matter; ADIP, acid detergent insoluble protein * and ** Significant by F-test at 5% and 1% probability respectively

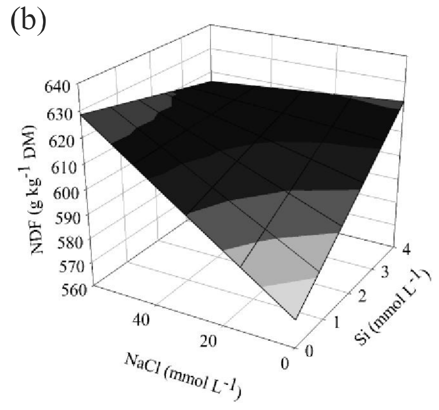
Figure 2 - Chemical and bromatological composition (g.kg^{-1} DM) of the aerial part of *Brachiaria brizantha* ‘MG5’ for concentrations of Si and NaCl in the nutrient solution for the first cut

(a)



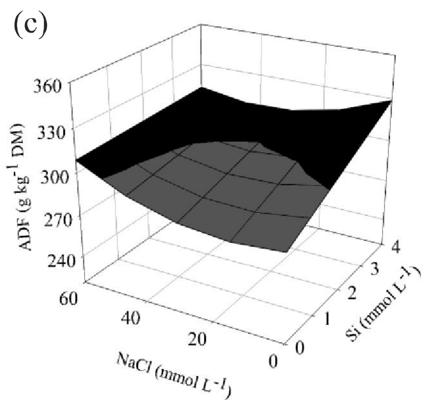
$Y = 106{,}3637 - 1{,}5459^{*}Si - 0{,}2514^{**}NaCl$
$R^2 = 0{,}82$

(b)



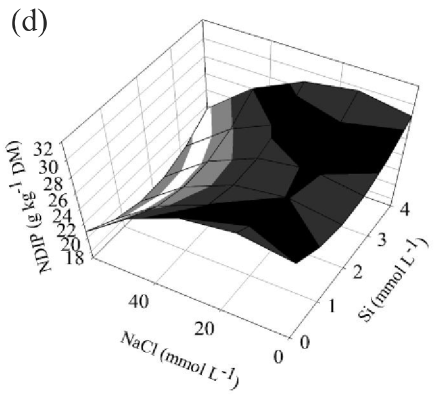
$Y = 571{,}198 + 12{,}748^{**}Si - 0{,}9556^{*}NaCl - 0{,}2656^{**}SiNaCl$
$R^2 = 0{,}43$

(c)



$Y = 282{,}968 + 11{,}467^{**}Si - 0{,}420NaCl + 0{,}01411^{**}NaCl^2 - 0{,}1749^{**}SiNaCl$
$R^2 = 0{,}43$

(d)



$Y = 27{,}972 - 3{,}073Si + 0{,}1216^{**}NaCl + 0{,}8126^{*}Si^2 - 0{,}003991^{**}NaCl^2$
$R^2 = 0{,}89$

* and ** Significant by F-test at 5% and 1% probability respectively

NDF increased in the presence of Si up to a concentration in the medium of 48 mmol L^{-1} NaCl (Figure 2b). Above this concentration of NaCl (48 mmol L^{-1}) there was a reduction in NDF in the presence of Si (Figure 2b). This reduction was from 628.50 g.kg^{-1} DM to 615.80 g kg^{-1} DM in plants grown with 0 and 4 mmol L^{-1} Si in the medium, and 60 mmol L^{-1} of NaCl (Figure 2b).

The reduction in NDF with the increase in Si in the medium, in plants grown with 60 mmol L^{-1} NaCl is not relevant to the change in forage nutrient value. The salinity accelerated plant senescence (Table 1) (AHMAD *et al*., 2013); this phenological change favours the lignification of plant tissue (TAIZ; ZEIGER, 2013) and a reduction in protein content (Figure 2a), which correlate with the increase in NDF (Figure 2b).

With the increase in NaCl concentrations in the medium, there was a reduction in the increases of ADF, the minimum value being obtained with 14.89 mmol L^{-1} NaCl (Figure 2c). The ADF increased in the presence of Si, with the maximum value (328.80 g kg^{-1} DM) obtained at a concentration of 4 mmol L^{-1} Si (Figure 2c).

ADF levels are related to the lignin content of the forage, which prevents microbial adherence and enzymatic hydrolysis of the cellulose and hemicellulose, making the structural carbohydrates unavailable. As a consequence, forages with ADF values greater than 400 g kg^{-1} DM adversely affect ingestion (BERCHIELLI; PIRES; OLIVEIRA, 2011). The values found in the present study would not affect the consumption of grazing animals, since the highest value (328.80 g kg^{-1} DM) found with 4 mmol L^{-1} Si and 0 mmol L^{-1} NaCl is below the level at which the consumption of forage is affected (Figure 2c).

With increasing concentrations of NaCl in the solution, the levels of NDIP increased up to 15.23 mmol L^{-1} NaCl (Figure 2d). There was also an increase in NDIP values as a function of the Si. The minimum value was 25.10 g kg^{-1} DM for 1.89 mmol L^{-1} Si (Figure 2d), which is related to the greater mobilisation of nitrogen (N) for structural glycoproteins with the increase in Si. Structural glycoproteins are related to an increase in cell-wall rigidity (RAVEN; EVERT; EICHHORN, 2014), which may be associated with accelerated senescence in plants and/or a physiological response to conditions of salt stress.

CP, crude protein (a); NDF, neutral detergent fibre (b); ADF, acid detergent fibre (c); NDIP, neutral detergent insoluble protein (d).

ADIP levels reduced as a function of the NaCl concentration up to 32.71 mmol L^{-1}, followed by an increase (Table 1). The minimum value obtained was 9.40 g kg^{-1} DM with 32.71 mmol L^{-1} NaCl (Table 1). The values for NDIP and ADIP are correlated with the nitrogen retained in the fibre, making it unavailable for microbial action.

Second and Third Cuts

SDW production in the *Brachiaria brizantha* ‘MG5’ in the second and third cuts reduced linearly with the increase in NaCl concentration (Table 2), where the minimum values were 7.26 and 28.59 g pot^{-1} respectively for 60 mmol L^{-1} NaCl (Table 2).

In the second and third cuts, although the salinity reduced tillering, the addition of Si to the plants under stress minimised the effects of the NaCl. In the second cut, plants grown with 60 mmol L^{-1} NaCl in the solution showed an increase in NT from 13 to 22 (Figure 3a), and in the third cut, from 9 to 34 tillers when the Si concentration increased (Figure 3b). The inclusion of Si increases the growth of many plant species through photosynthetic activity; this is due to the Si affording an increase in leaf area and chlorophyll content, and improving chloroplast structure in plants under salt stress (YIN *et al*., 2013).

The concentrations of Si and NaCl in the solution did not alter the NSL in the second and third cuts, where the mean values were 30 and 35 respectively; the NFT was also not altered in the last two cuts.

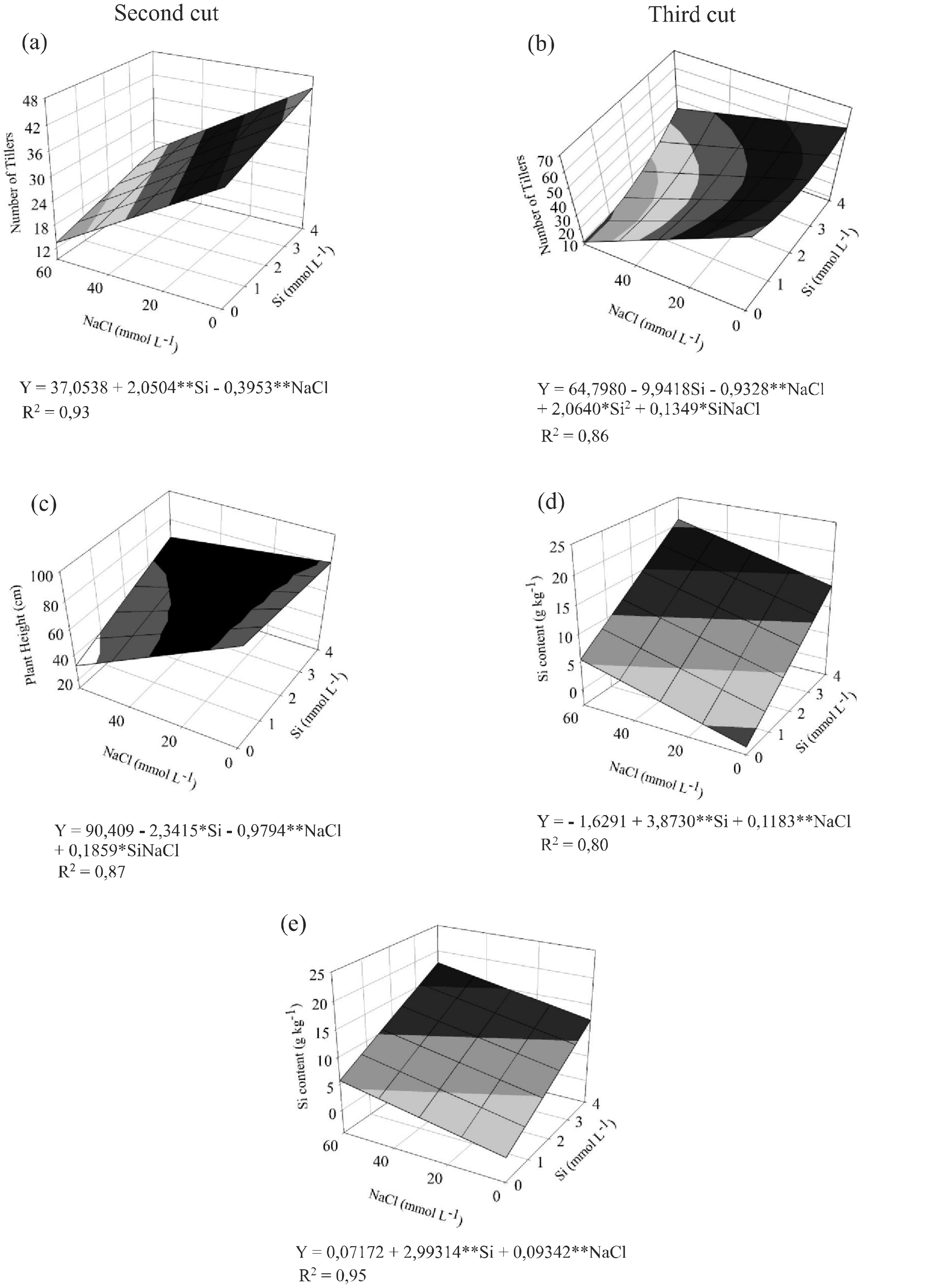
Plant height varied as a function of Si and NaCl in the nutrient solution only for the second cut (Figure 3c). With the salinity, there was a reduction in plant height. However, with the increase of Si in the medium, plant height increased from 31.64 to 66.90 cm in the plants grown with 0 and 4 mmol L^{-1} Si respectively, and with 60 mmol L^{-1} NaCl, demonstrating the effect of

Table 2 - Growth, and chemical and bromatological composition (g.kg^{-1} DM) in *Brachiaria brizantha* ‘MG5’ for isolated concentrations of NaCl or Si in the nutrient solution for the second and third cuts

Variable[a]	Equation	R^2
Second cut		
SDW (g pot^{-1})	Y = 44.9853 - 0.6286**NaCl	0.92
DM (g kg^{-1} NM)	Y = 333.2711 - 0.5894**NaCl	0.99
CP	Y = 79.9209 + 2.0737**NaCl - 0.0274**$NaCl^2$	0.89
NDIP	Y = 24.206 + 1.352**Si	0.81
ADIP	Y = 6.450 + 1.482*Si - 0.2891**Si^2	0.94
Third cut		
SDW (g pot^{-1})	Y = 81.9051 - 0.8887**NaCl	0.96
NDIP	Y = 19.3853 + 0.1364**NaCl	0.79

[a] SDW, shoot dry weight; DM, dry matter; CP, crude protein; NDIP, neutral detergent insoluble protein; ADIP, acid detergent insoluble protein; * and ** Significant by F-test at 5% and 1% probability respectively

Figure 3 - Number of tillers (a, b), height (c) and Si content (d, e) in the aerial part of *Brachiaria brizantha* ‘MG5’ for concentrations of Si and NaCl in the nutrient solution for the second and third cuts



and ** Significant by F-test at 5% and 1% probability respectively

Si on plants under conditions of salt stress (ASHRAF *et al*., 2010, MOUSSA, GALAD, 2015; YIN *et al*., 2013).

In the third cut however, there were no changes in plant height for the concentrations of Si and NaCl in the solution, the mean value being 52.87 cm.

In general, Si minimised the harmful effects of salinity on growth in the second and third cuts only. Plants of *B. brizantha* 'MG5' under stress and supplied with Si, displayed better regrowth compared to plants with no Si. The mechanisms that explain this result are related to the biochemical, physiological and photosynthetic aspects of the plants (ABDALLA, 2011; PARVEEN; ASHRAF, 2010), which can be better evaluated in future studies. In the second and third cuts, the Si content increased in the aerial part of *B. brizantha* 'MG5' as a function of NaCl and Si concentrations in the solution (Figure 3d and 3e). The increase in Si content in the plant tissue as a function of NaCl in the medium is due to the effect of the concentration, as there was a reduction in plant growth (Table 2).

For the second cut, the DM content was reduced as a function of the NaCl concentration in the medium (Table 2). Due to the excess of the Na^+ and Cl^- ions in the chloroplasts, there is a restriction on water absorption. As an immediate consequence of this salinity-induced water deficit, plant growth becomes slower in an attempt to survive amid the stress (AHMAD *et al*., 2013; RAHIMI *et al*., 2012). For the third cut, there was no fit of the mathematical model for DM content as a function of Si and NaCl concentrations in the medium, showing a mean value of 415.20 g kg^{-1} NM.

The OM content was reduced as a function of the NaCl concentration in the solution, and increased as a function of the Si for the second and third cuts (Figure 4a and 4b).

MM levels increased with increases in the NaCl concentration in the solution for the second and third cuts, (Figure 4c and 4d). In the second cut, there was a quadratic effect due to the Si. In the plants grown without NaCl, the highest value (81.30 g kg^{-1} DM) for MM was obtained with 4 mmol L^{-1} Si (Figure 4c).

Plants cultivated with Si show greater ion absorption efficiency (MOUSSA; GALAD, 2015), resulting in a greater value for MM. In plants under stress, the highest value for MM was obtained with 0 mmol L^{-1} Si. Plants under salt stress and with no Si displayed a marked reduction in growth (Table 2), which may have led to the accumulation of MM.

There was a quadratic adjustment of CP levels as a function of NaCl for the second (Table 2) and third cuts (Figure 4e). Also in the third cut, there was a quadratic adjustment of CP levels as a function of the Si, with the greatest value (105.80 g kg^{-1} DM) obtained with 44.38 mmol L^{-1} NaCl and 1.95 mmol L^{-1} Si (Figure 4e). Even with Si promoting changes in CP values, these were not enough to alter the chemical or bromatological composition. The increase in CP as a function of the NaCl can be explained by the effect of the concentration. The plants reduced their growth, thereby increasing the leaf to stem ratio and consequently the CP.

There was a decreasing linear effect on NDF levels with the increasing concentrations of NaCl in the second cut. There was an increase in NDF levels as a function of the Si, however this increase had no relevance in changing the value of this variable (Figure 5a).

In the third cut, there was reduction NDF levels as a function of the NaCl and Si. The lowest value was 567.10 g kg^{-1} DM with 60 mmol L^{-1} NaCl and 4 mmol L^{-1} Si (Figure 5b).

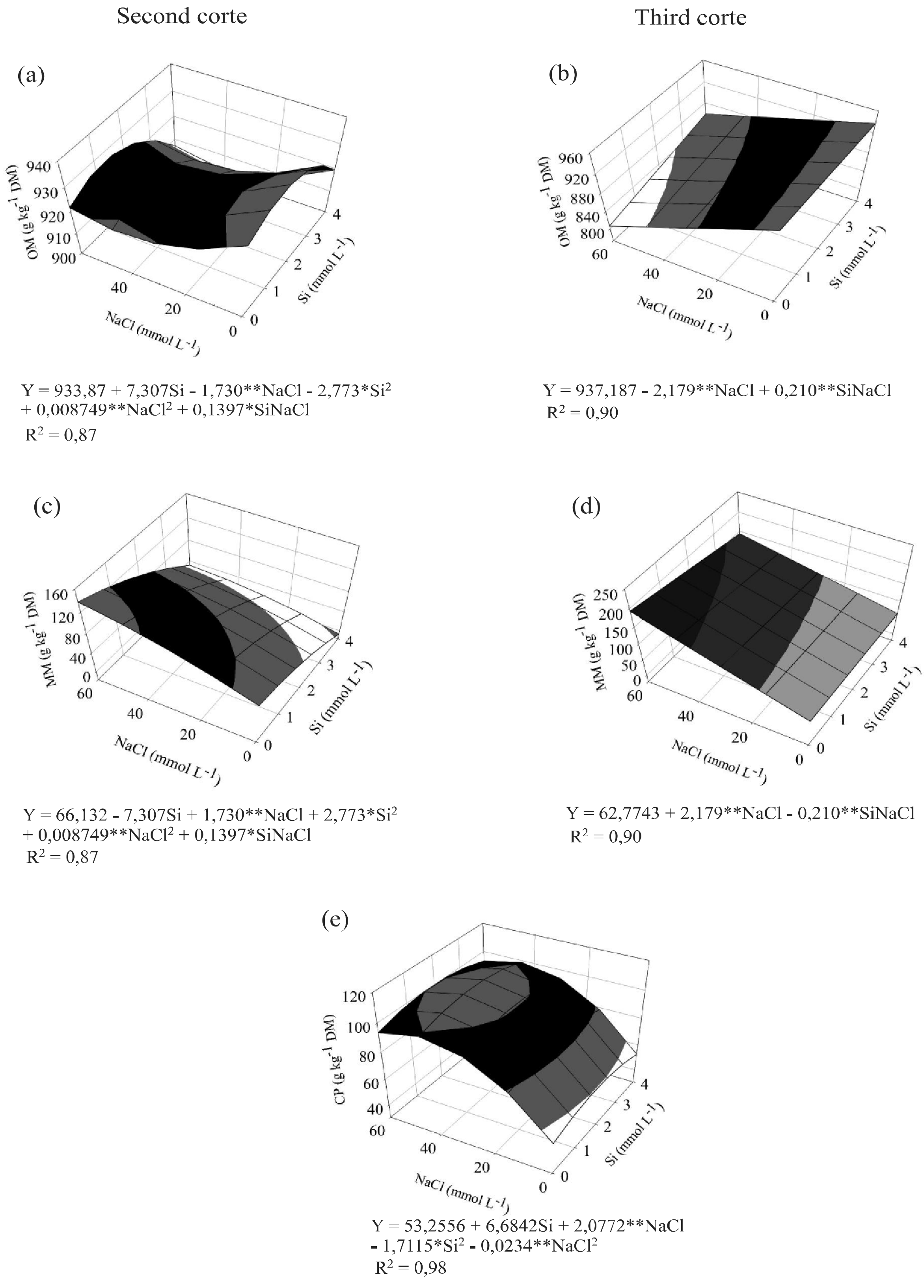
The reduction in NDF values with the increase in NaCl is due to the smaller vegetative growth of the forage under stress conditions, as confirmed by the growth variables (Table 2), with less cell expansion, and a consequent reduction in cell-wall constituents.

ADF levels were reduced as a function of the NaCl in the solution. In the second cut, the minimum value was 250.00 g kg^{-1} DM with 50.54 mmol L^{-1} NaCl (Figure 5c). However, with the increase in Si, there was an increase in ADF (Figure 5c). In the third cut, the ADF reduced as a function of the NaCl in the solution, the lowest value being obtained with 60 mmol L^{-1} NaCl. A quadratic effect was seen for increases in Si concentration, where the minimum value was 368.00 g kg^{-1} DM, obtained with 1.92 mmol L^{-1} Si (Figure 5d).

For the second cut, there was an increase in the levels of NDIP in the aerial part of *B. brizantha* 'MG5'as a function of the Si. The maximum value for NDIP (29.60 g kg^{-1} DM) was obtained with 4.0 mmol L^{-1} Si (Table 2). For the third cut, the NaCl concentration increased the levels of NDIP, with a high value of 27.60 g kg^{-1} DM with 60 mmol L^{-1} NaCl (Table 2).

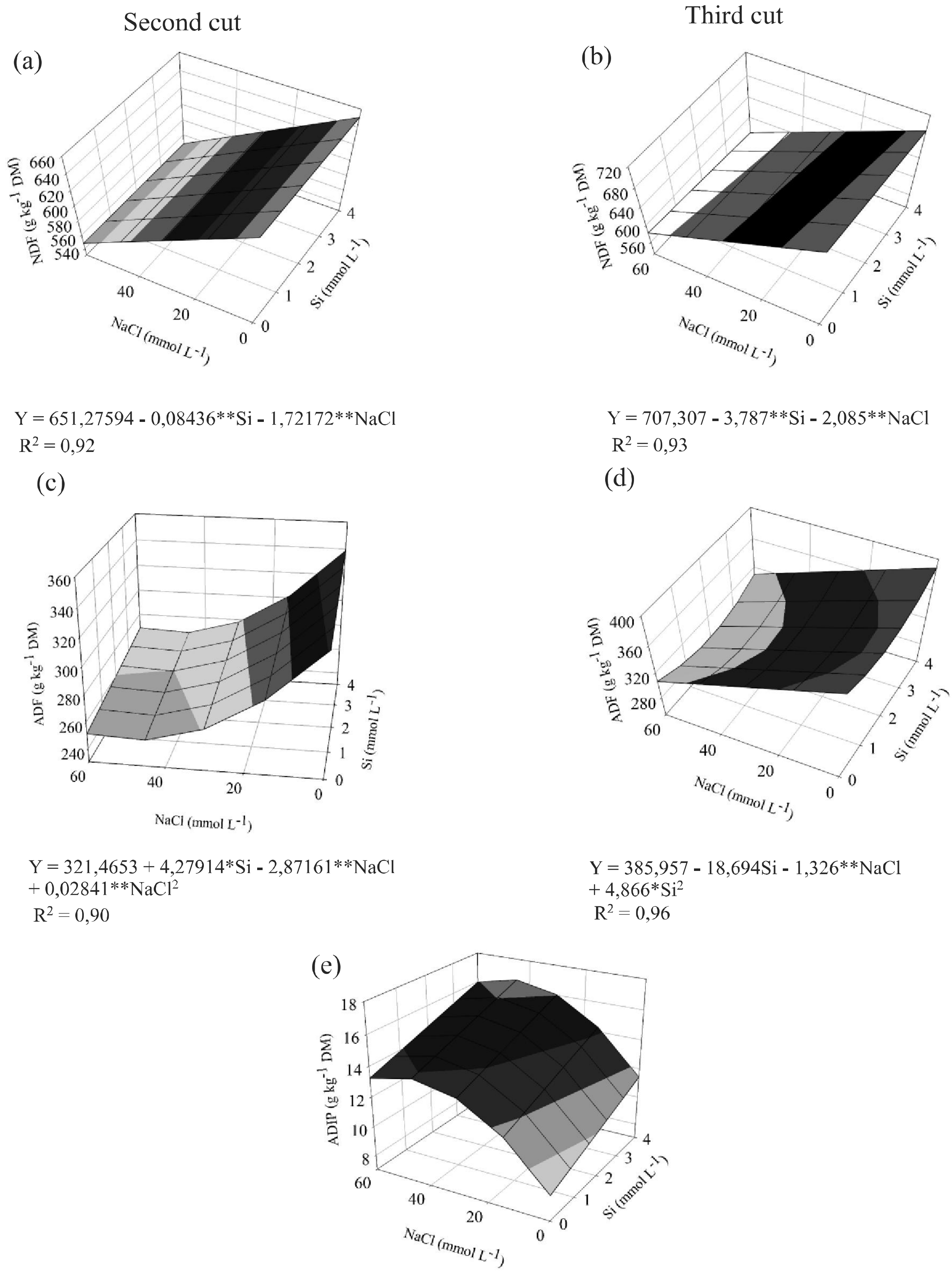
Values for ADIP in the second cut increased as a function of the Si (Table 2). In the third cut, the ADIP content increased with the NaCl and Si concentrations (Figure 5e). The values for ADIP are correlated with the nitrogen retained in the fibre, which is not available for the action of ruminal micro-organisms.

Figure 4 - Organic matter (a, b), mineral matter (c, d) and crude protein (e) in the aerial part of *Brachiaria brizantha* ‘MG5’ under concentrations of Si and NaCl in the nutrient solution for the second and third cuts



* and ** Significant by F-test at 5% and 1% probability respectively

Figure 5 - Neutral detergent fibre (a, b), acid detergent fibre (c, d), and acid detergent insoluble protein (e) in the aerial part of *Brachiaria brizantha* ‘MG5’ for concentrations of Si and NaCl in the nutrient solution for the second and third cuts



(a) $Y = 651{,}27594 - 0{,}08436^{**}Si - 1{,}72172^{**}NaCl$, $R^2 = 0{,}92$

(b) $Y = 707{,}307 - 3{,}787^{**}Si - 2{,}085^{**}NaCl$, $R^2 = 0{,}93$

(c) $Y = 321{,}4653 + 4{,}27914^{*}Si - 2{,}87161^{**}NaCl + 0{,}02841^{**}NaCl^2$, $R^2 = 0{,}90$

(d) $Y = 385{,}957 - 18{,}694Si - 1{,}326^{**}NaCl + 4{,}866^{*}Si^2$, $R^2 = 0{,}96$

(e) $Y = 8{,}689 + 0{,}6817^{**}Si + 0{,}2314^{**}NaCl - 0{,}002592^{**}NaCl^2$, $R^2 = 0{,}91$

* and ** Significant by F-test at 5% and 1% probability respectively

CONCLUSION

The concentration of 4.0 mmol L^{-1} silicon reduces the damaging effects of sodium chloride on regrowth in *B. brizantha* 'MG5', with advancement of the phenological cycle improving growth. However, the silicon levels under study are not sufficient to give satisfactory results in relation to a reduction in salt stress as regards quality and the production of forage weight in *B. brizantha* 'MG5'.

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