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Effect of sources and doses of acidifiers on pH of soil collected from floor of chicken housing facilities

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ABSTRACT

Acidification of animal manure has been one of the approaches used to combat the proliferation of bacteria and high volatilization of ammonia (NH_3). Conversely, alkalinization is performed with basic oxides in Brazil, which raises the pH of the litter and soil from floors of chicken facility, creating a constant source of contamination in them. In this context, this study was undertaken to examine the effect of sodium bisulfate (SB) and elemental sulfur (ES) on the acidification of different soils from floor of chicken housing facilities, considering their efficiency and reaction time. The experiment involved tree soils collected inside chicken facilities (at six, 36, and 60 months of occupation), as well as soil that was collected outside the facilities, totaling four sampling sites. Both acidifier sources—SB and ES—were applied at six increasing doses (0, 2, 3, 6, 12, and 24 $cmol_c\ kg^{-1}$ of H^+ in the 3-cm soil layer), and incubated for up to 53 days. At the end of each incubation period, the pH of the soil was measured. The results suggest that SB is efficient in reducing the pH of chicken soil, with an immediate reaction occurring after its application. Under the conditions adopted in the present study, the recommended dose of SB to reduce the pH to 5.0 was 6 $cmol_c\ kg^{-1}$ of H^+, which corresponded to the application of 7.2 g of the product in 500 g of soil. Elemental sulfur showed a slow reaction and low efficiency. The use of SB quickly and efficiently provides the acidification of soil from floor of chicken housing facilities.

Keywords: Acidification, Broiler production, Chicken litter, Poultry house management.

Efeito de fontes e doses de acidificantes no pH do solo coletado do piso de galinheiros

RESUMO

A acidificação de resíduo de animais vem sendo uma das maneiras de combater proliferação de bactérias e a alta volatilização de amônia (NH_3). No Brasil, contrariamente, procede a alcalinização com óxidos básicos com elevação do pH da cama e solo do piso dos aviários, criando neste último uma fonte constante de contaminação. Neste sentido, este estudo teve como objetivo verificar o efeito de Bissulfato de sódio (SB) e enxofre elementar (ES) na acidificação de diferentes solos do piso de aviário, quanto a eficiência e tempo de reação. Utilizou-se três solos coletados dentro de galpões de criação de frango (6, 36 e 60 meses de ocupação), além da coleta do solo externo ao aviário, totalizando quatro locais de amostragens. As duas fontes de acidificantes, o SB e o ES foram aplicadas em 6 doses crescentes (0, 2, 3, 6, 12 e 24 $cmol_c\ kg^{-1}$ de H^+ na camada de 3 cm de solo), incubados até 53 dias. Ao final de cada período de incubação determinou-se o pH do solo. Os resultados do presente estudo permitiram concluir que o SB é eficiente na redução do pH do solo de aviário com reação imediata após sua aplicação. Nas condições do presente estudo a dose indicada de SB para reduzir o pH para 5,0 foi de 6 $cmol_c\ kg^{-1}$ H^+ que correspondeu a aplicação de 7,2 g do produto em 500 g de solo. O ES elementar mostrou reação lenta e baixa eficiência. Acidificação do solo do aviário pode ser obtido rapidamente e eficientemente com uso de SB.

Palavras-chave: Acidificação, Cama de frango, Produção de frangos de corte, Manejo de aviário.

1. Introduction

Brazil is among the largest chicken meat producers in the world, having ranked 3rd in 2020 with 13.8 million tons produced, only behind China and the United States. As an exporter, it ranks first, with 4.2 million tons of the product exported in 2020 (CIAS, 2021). The state of Paraná is the largest producer of chicken meat in the country, accounting for 33% of all national production (IBGE, 2022) and strongly impacting capital collection and job creation for the state.

Broiler production systems adopt the chicken litter, which is distributed throughout the facility floor and whose purpose is to ensure the comfort of the birds. The material is capable of absorbing part of the humidity, diluting urates and feces, reducing the production of dust and ammonia, preventing the proliferation of insects and exposure to disease-transmitting agents, providing thermal insulation, and decreasing injuries to the breast, knee, and footpad of birds (Ávila et al., 1992; De Angelo et al., 1997; Santos et al., 2012).

Wood shavings are the material most commonly used as chicken litter in Brazil, and are reused for several cycles. At the end of each production cycle, calcium oxide (CaO) is applied to improve the hygiene conditions of the litter. However, the application of CaO leaves the litter and soil with an alkaline pH, a condition that favors the formation of ammonia and the activity of some bacteria (Mendes et al., 2016, Vaz, 2022). High levels of ammonia—around 50 ppm—can damage the respiratory and locomotor systems and eyes of birds (Oro and Guirro, 2014).

Most chicken facilities in the state of Paraná use stripped soil as flooring as a way to reduce costs and facilitate drainage. In this way, these soils receive all the loads that leach from the litter and can likely become a potential source of ammonium and microorganisms for the new litter over time. Therefore, it is also important to take care of the chicken soil to reduce this potential contaminant. Studies indicate that acidic environments are favorable for chicken production, as they limit the growth of undesirable bacteria and the volatilization of ammonia (Gonçalves et al., 2019; Pope and Cherry, 2000). A study in which organic acids were applied to chicken litter showed that acidification reduced microbial proliferation 14 days after application of the acidifier (Aniecevski et al., 2022).

Some products, such as elemental sulfur and sodium bisulfate, can be used as chemical chicken litter conditioners (Pope and Cherry, 2000; Line and Bailey, 2006). Nonetheless, studies involving the use of acidifiers have been mostly carried out in chicken litter, with few examining the soil. Given the above scenario, the present study was undertaken to evaluate the effect of acidifying sources and their doses in reducing the pH of chicken soil.

2. Material and Methods

The experiment was conducted at the Soil Chemistry and Fertility Laboratory of the Agricultural Sciences unit at the Federal University of Paraná. Soil samples were collected from three chicken facilities with dirt floors, located in Paranavaí-PR, Brazil, at different shavings-litter occupation times (six, 36, and 60 months). Additionally, soil from the external area of the chicken facility was also collected, totaling four sampling sites. These facilities were close together. Soil samples from the four sites were collected on the same day, from the 0-10 cm depth layer. These were dried in the shade, crushed in a mortar to completely break up the soil, and sieved through a 2.0-mm mesh to remove impurities.

The experiment was laid out in a completely randomized design with a 2 × 6 factorial arrangement consisting of two sources of acidifiers [sodium bisulfate (SB) and elemental sulfur (ES)] and six equivalent doses, with four replications for each type of soil. The doses were established so as to release 0, 2, 3, 6, 12, and 24 $cmol_c$ kg^{-1} of H^+ in the 3-cm soil layer. Sodium bisulfate ($NaHSO_4$) has a molecular weight of 120 g, and 1 g or 100 $cmol_c$ of H^+, so 120 g of $NaHSO_4$ can release 100 $cmol_c$ of H^+. Elemental sulfur needs to be oxidized by bacteria; therefore, through the stoichiometric reaction, 16 g of S also releases 100 $cmol_c$ of H^+. Accordingly, the SB doses tested were 0 (control), 1.8, 3.6, 7.2, 14.4, and 28.8 g; and the ES doses were 0, 0.24, 0.48, 0.96, 1.92, and 3.84 g.

The experimental units consisted of transparent plastic bags that received 500 g of soil and the SB or ES doses. The acidifier and soil in each container were mixed thoroughly. All bags treated with ES were closed to raise the temperature so that the acidifier could react. Treatments were incubated for zero, four, 18, 25, 32, 39, 46, and 53 days, maintaining soil moisture at 40% of field capacity. The soil pH was determined at the end of each incubation period. To this end, the total soil of each bag was homogenized, followed by the removal of 10 cm^3 of soil; then, the pH was determined in $CaCl_2$ at 0.01 mol L^{-1} (Raij et al., 2001).

Statistical analyses were performed separately for each soil type. The pH values were subjected to analysis of variance (F test), and when there was a significant difference, they were subjected to first- and second-degree regression analysis. The mathematical model with the lowest level of significance (always less than 5% probability by the F test) was chosen. Sisvar 4.2 statistical software was employed.

3. Results and Discussion

Both the acidifier sources and their doses had a significant effect on soil pH. The sources differed greatly in their ability to acidify the soils. Elemental sulfur altered the soil pH from 11 days of incubation in all soils, whereas SB induced changes at the beginning of incubation (Figures 1 to 8). The doses of ES and SB required to acidify the soil were found to be very different, showing that there are distinctions between the sources regarding their H^+ release ability.

The best-fitting equations for ES were the linear ones, demonstrating that the higher the dose of this source, the greater the reduction of soil pH. However, none of the ES doses, with an incubation period of up to 53 days, was able to reduce the pH below 5.0 in the different soils. Even with high ES doses, the pH of the soils changed little and remained alkaline, which indicates that ES did not have an adequate reaction in the soils and did not release enough H^+ ions for acidification, although the applied rate was calculated for that release (Figures 1 to 8).

The fact that ES is unable to reduce the pH to 5.0 may be related to its dependence on microbial activity, which is favored in environments with ideal humidity, temperature, and aeration (Boaro et al., 2014, Orman and Kaplan, 2011). Depending on these factors, this reaction can take several months if conditions are not ideal. Other factors, such as texture and organic matter content, can also influence reaction time, due to their buffering effect (Novais et al., 2007). According to Sierra et al. (2007) when calculating the ES dose to be used to acidify the soil, factors such as organic matter content, pH, and carbonate content of the soil should be taken into account.

For SB, the dose of 3 $cmol_c\ kg^{-1}\ H^+$, which corresponded to 3.6 g of the acidifier, was sufficient to lower the pH to acidic levels, demonstrating greater effectiveness of this acidifier in reducing the pH of chicken soils (Figures 3 to 8). Unlike ES, the reaction of SB is chemical, and due to its high solubility, it has an immediate reaction, as also observed by Line and Bailey (2006) and McWard and Taylor (2000) in chicken litter.

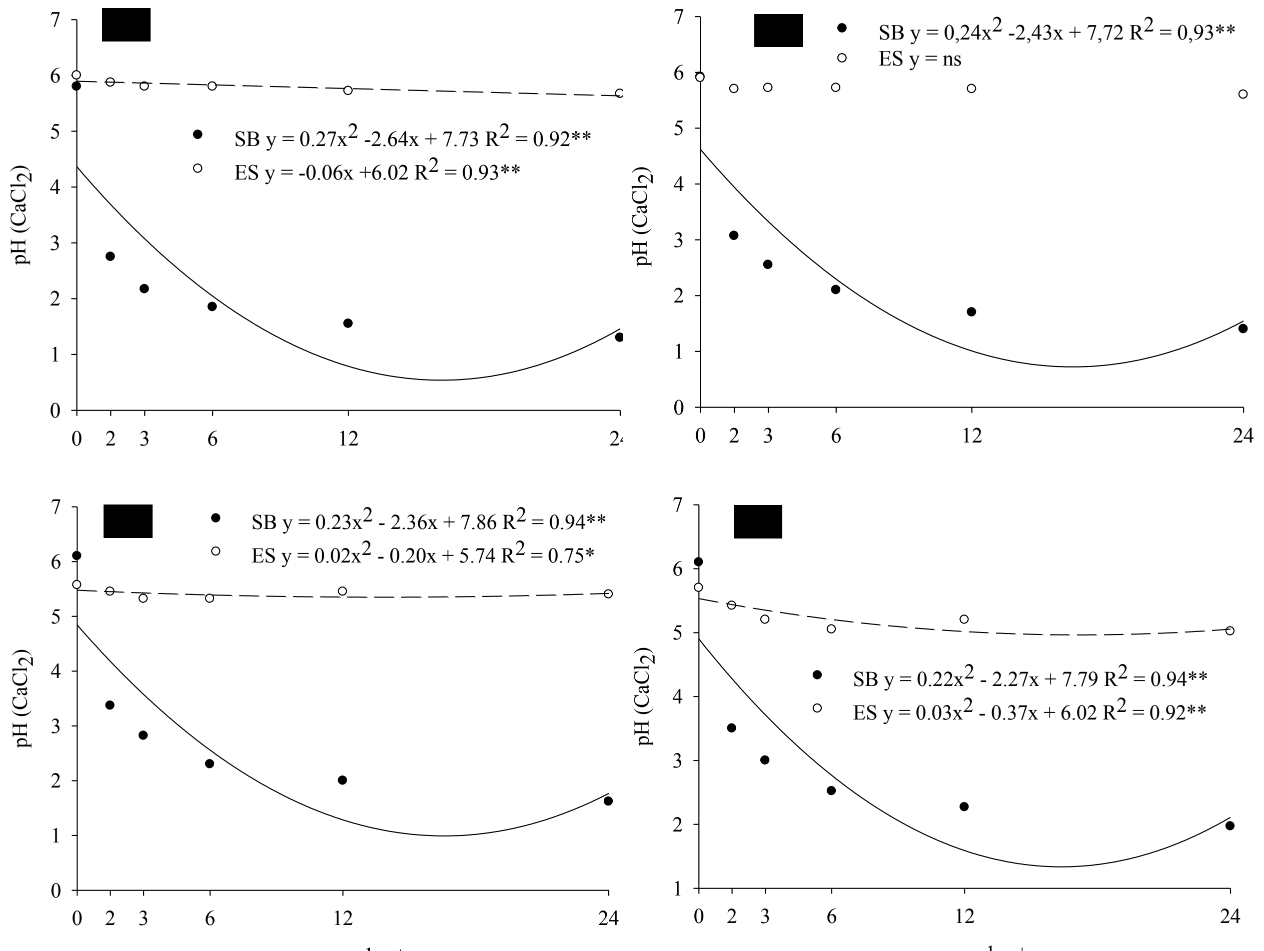

Figure 1. pH values of the soil in the external area of the chicken facility as a function of the application of sodium bisulfate (SB) and elemental sulfur (ES) doses, at different incubation periods. A: zero incubation; B: four days; C: 11 days; D: 18 days. * and ** significant at 5% and 1% probability, respectively.

For all soils under study, the regression equations that best fitted the pH as a function of bisulfate doses were quadratic. This fit reveals that dose increases provide a maximum reduction of the pH, which was close to that detected at the dose of 12 $cmol_c\ kg^{-1}\ H^+$, or 14.4 g of SB. It also shows that after reaching this minimum value, doses above this value tend to decrease the acidification power of SB, causing a slight increase in soil pH (Figures 3 to 8). The pH values in all soils under SB application were lower in the first 11 days of incubation and showed a slight increase occurring over the incubation weeks, due to the buffering effect of the soil. Even with a small increase, the pH remained acidic with doses above 2 $cmol_c\ kg^{-1}\ H^+$, or 1.8 g of SB (Figures 3 to 8).

The rapid acidification provided by SB is very beneficial as some pathogens such as *Salmonella* spp. have the ability to regulate cytoplasmic pH near neutral conditions when exposed to mild declines in pH. However, when the external pH levels are much lower than the internal one, this process becomes strenuous, usually leading to cell death. Thus, abrupt reductions in litter pH and levels below 4.5 can have a bactericidal effect on *Salmonella* spp. and *Campylobacter* spp (Line, 2002). Overall, the initial pH of the soils using chicken litter was above 8.4 (Figures 3 to 8), whereas the external area (control) had a soil pH around 6 (Figures 1 and 2).

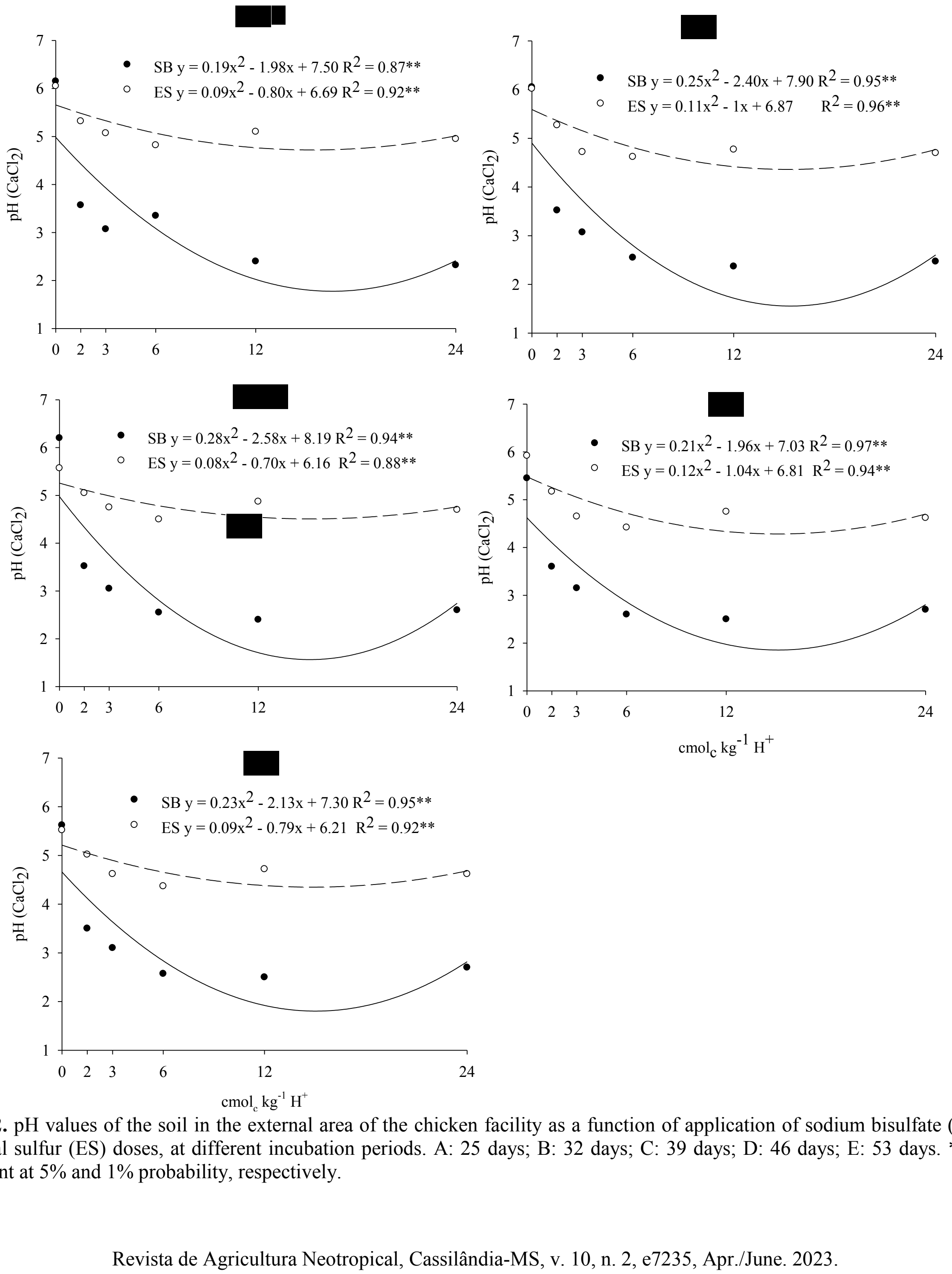

Figure 2. pH values of the soil in the external area of the chicken facility as a function of application of sodium bisulfate (SB) and elemental sulfur (ES) doses, at different incubation periods. A: 25 days; B: 32 days; C: 39 days; D: 46 days; E: 53 days. * and ** significant at 5% and 1% probability, respectively.

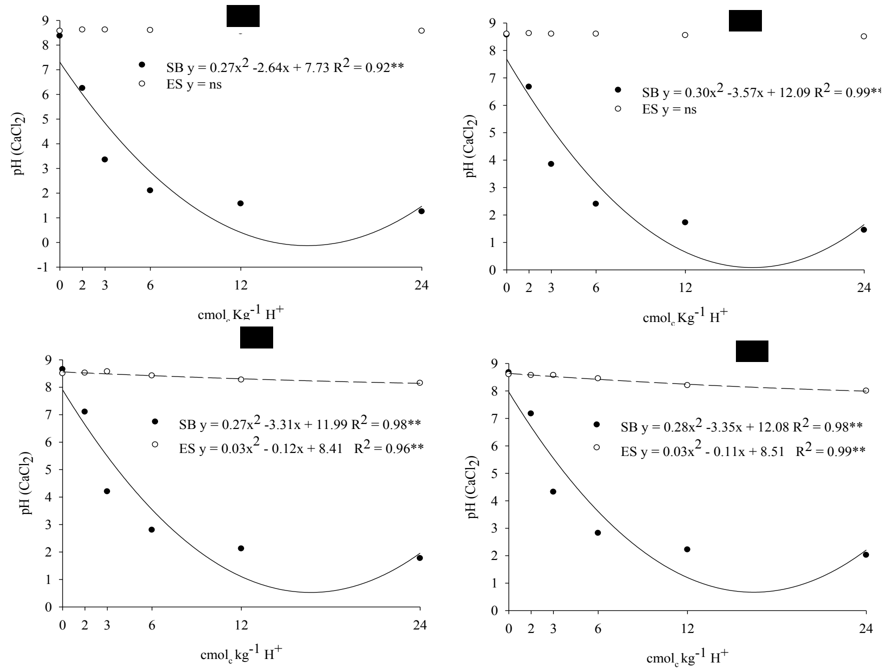

Figure 3. Soil pH values as a function of the application of sodium bisulfate (SB) and elemental sulfur (ES) doses, at different incubation periods. Soil occupied for six months. A: zero incubation; B: four days; C: 11 days; D: 18 days. * and ** significant at 5% and 1% probability, respectively.

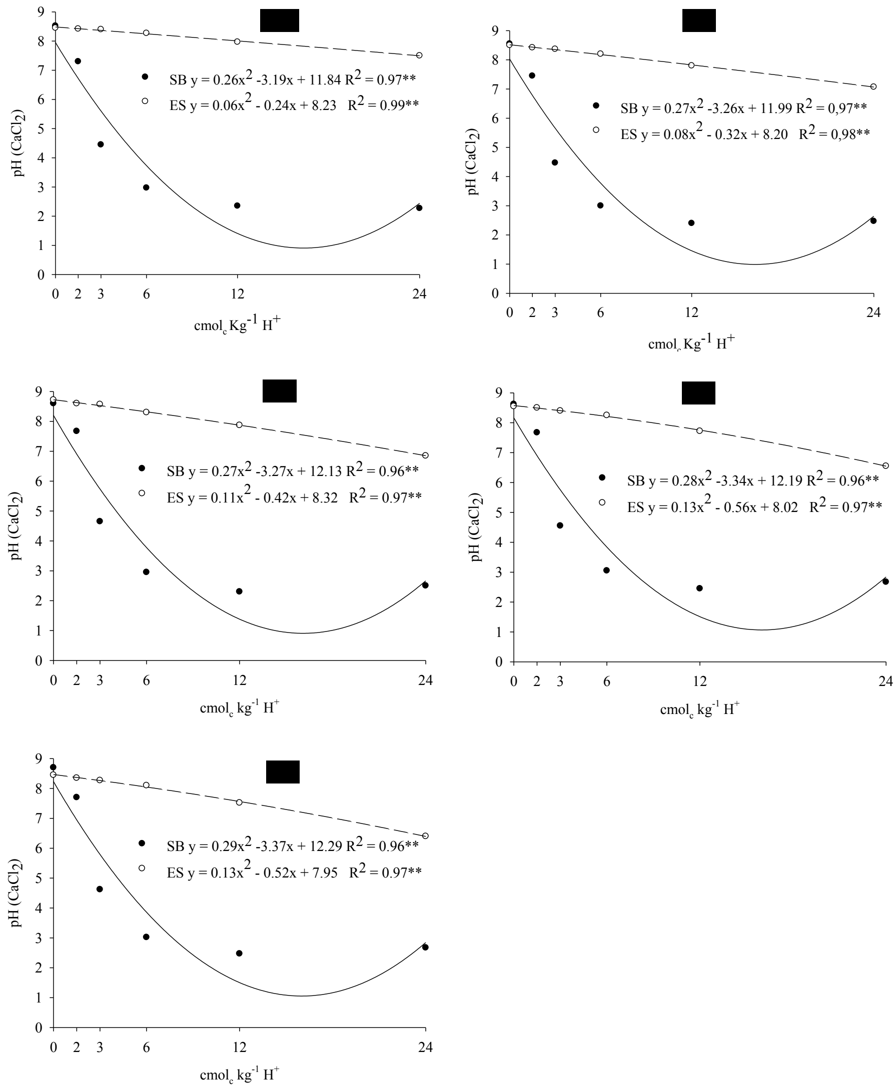

Figure 4. Soil pH values as a function of the application of sodium bisulfate (SB) and elemental sulfur (ES) doses, at different incubation periods. Soil occupied for six months. A: 25 days; B: 32 days; C: 39 days; D: 46 days; E: 53 days. * and ** significant at 5% and 1% probability, respectively.

A pH value above eight indicates that the chicken litter at the study site was treated with quicklime, with possible accumulation of $CaCO_3$ (carbonation reaction) and increased buffering power of the litter, which can be transferred to the soil. This would be especially true with a longer use of the litter, which would require a greater release of H^+ to affect the pH of this soil. It is worth remembering that this alkaline pH condition may result in the release of ammonia as well as decomposition of uric acid (Terzich and Goodwin, 1998).

As regards the soils with different usage times, there was a difference in the dose necessary to reach the pH value of 5.0. While SB doses close to 3 $cmol_c\ kg^{-1}\ H^+$,or 3.6 g of the product were sufficient for the soil with six months of use (Figures 3 and 4), the necessary SB dose for the soil at 60 months of use was around 6 $cmol_c\ kg^{-1}\ H^+$, or 7.2 g of the product (Figures 7 and 8). This result indicates that the longer the soil with chicken litter is used, the more resistant it becomes to having its pH changed (i.e. its buffering power increases), and this is related to the greater number of CaO applications in the treatment of chicken litter. Although the soils with longer use exhibited greater resistance to pH changes, SB application allowed them to reach pH values close to 5.0 with the dose of 6 cmolc $kg^{-1}\ H^+$ already at four days of incubation, keeping this pH slightly acidic until the 53rd day of incubation (Figures 7 and 8).

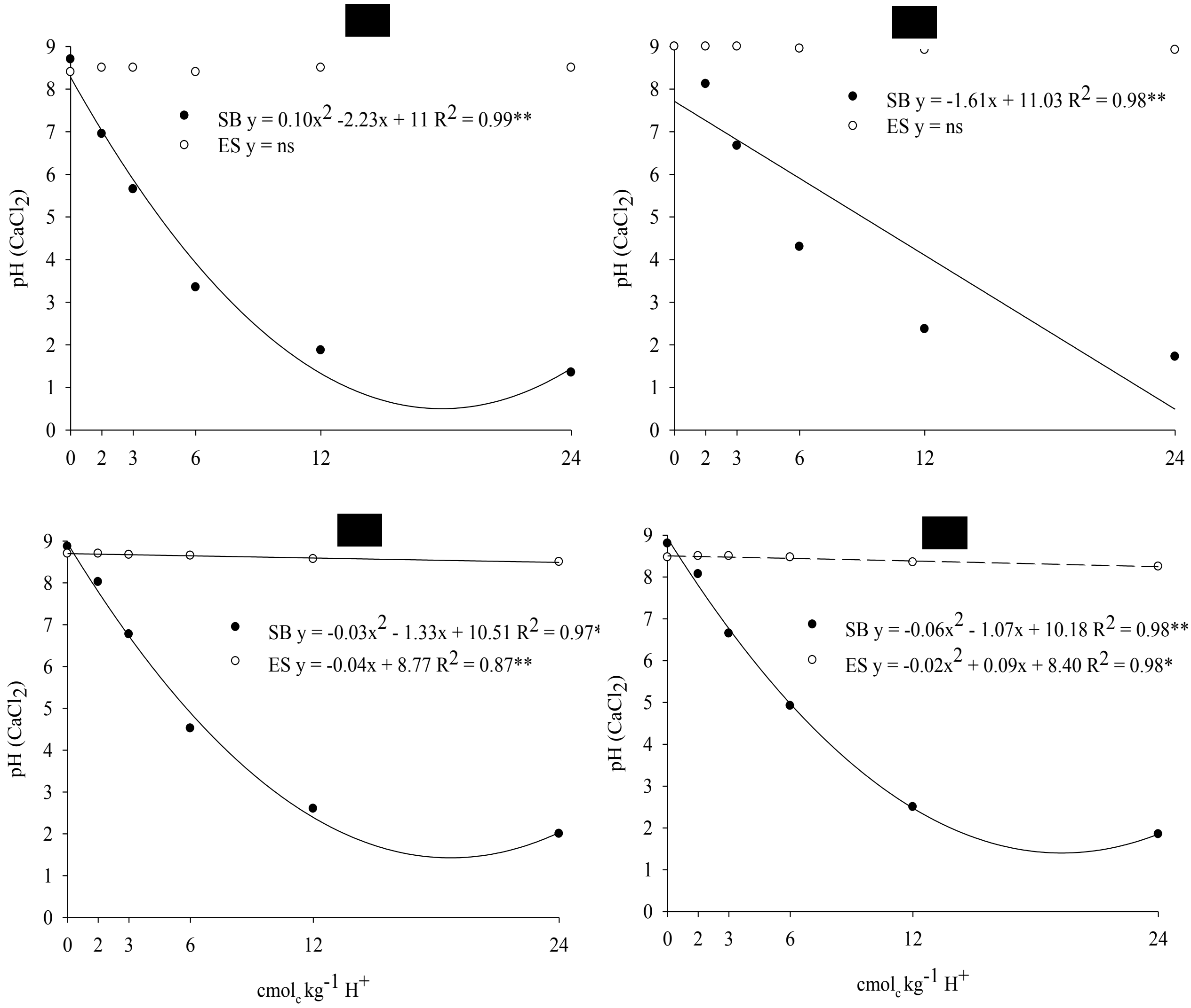

Figure 5. Soil pH values as a function of the application of sodium bisulfate (SB) and elemental sulfur (ES) doses, at different incubation periods. Soil occupied for 36 months. A: zero incubation; B: four days; C: 11 days; D: 18 days. * and ** significant at 5% and 1% probability, respectively.

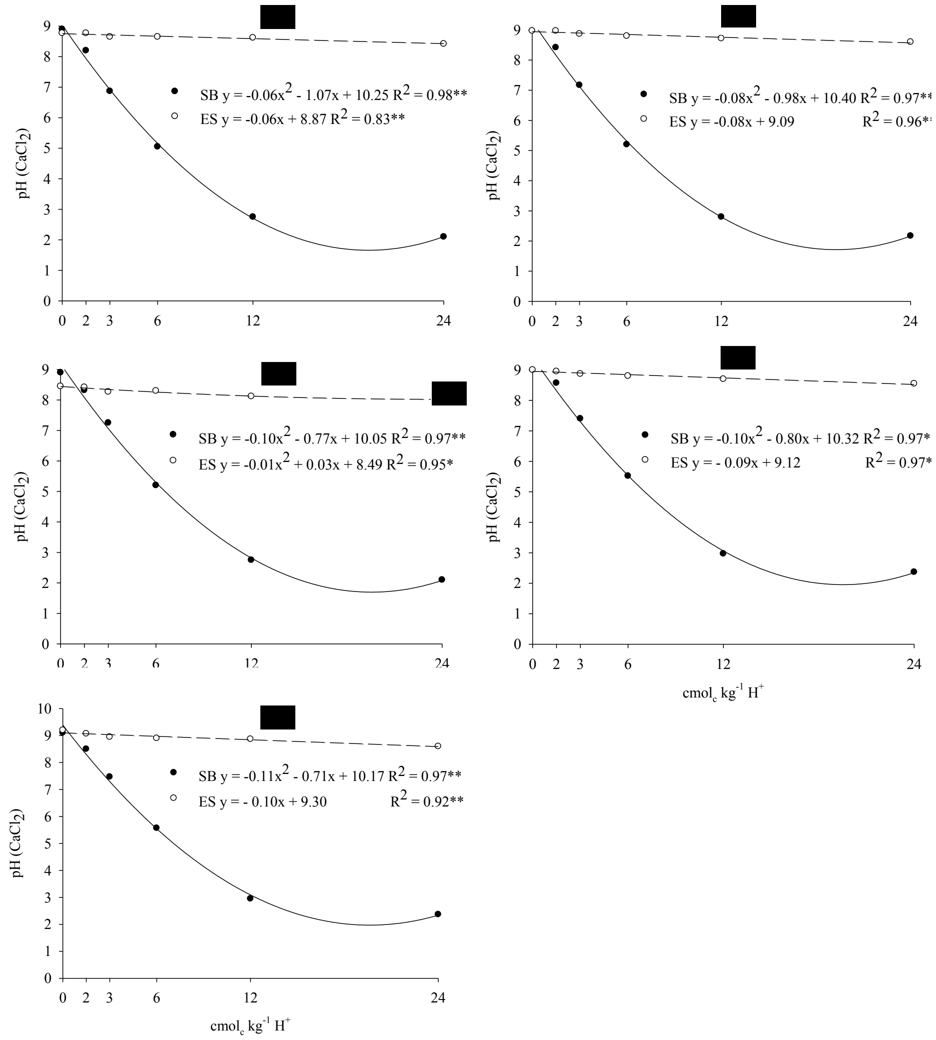

Figure 6. Soil pH values as a function of the application of sodium bisulfate (SB) and elemental sulfur (ES) doses, at different incubation periods. Soil occupied for 36 months A: 25 days; B: 32 days; C: 39 days; D: 46 days; E: 53 days. * and ** significant at 5% and 1% probability, respectively.

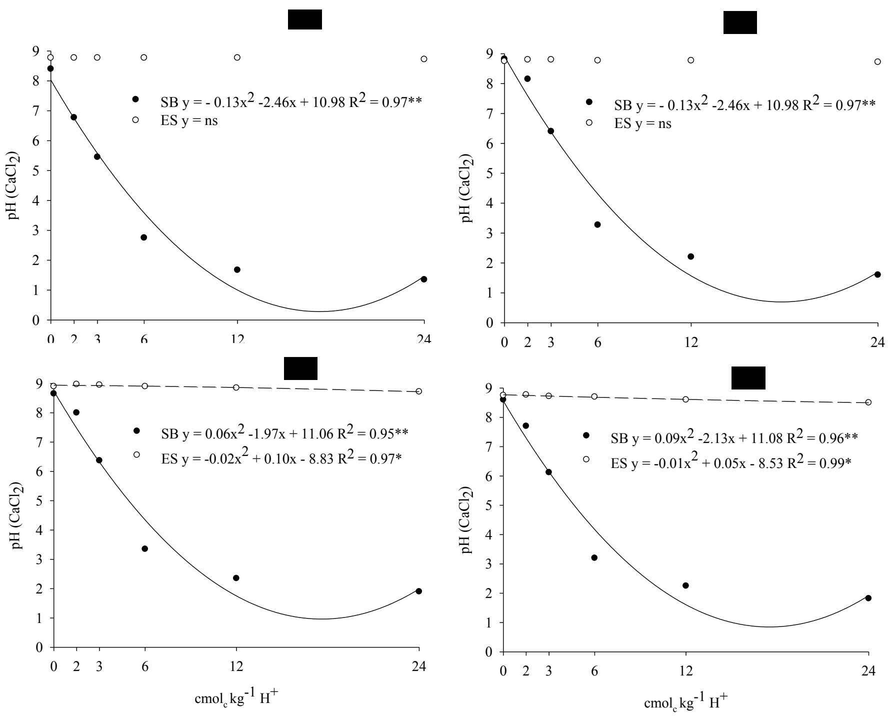

Figure 7. Soil pH values as a function of the application of sodium bisulfate (SB) and elemental sulfur (ES) doses, at different incubation periods. Soil occupied for 60 months. A: zero incubation; B: four days; C: 11 days; D: 18 days. * and ** significant at 5% and 1% probability, respectively.

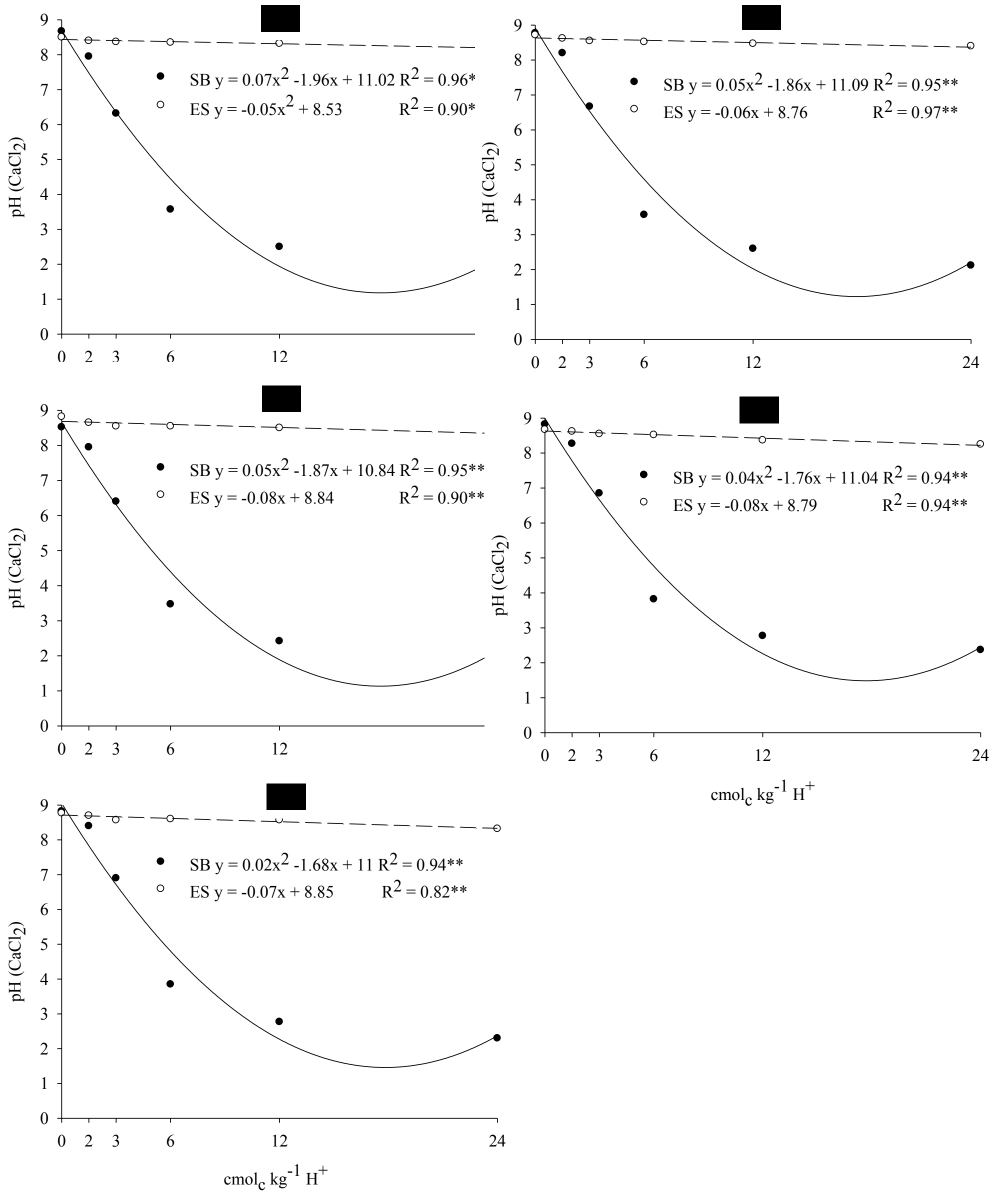

Figure 8. Soil pH values as a function of the application of sodium bisulfate (SB) and elemental sulfur (ES) doses, at different incubation periods. Soil occupied for 60 months. A: 25 days; B: 32 days; C: 39 days; D: 46 days; E: 53 days. * and ** significant at 5% and 1% probability, respectively.

4. Conclusions

Sodium bisulfate is efficient in reducing soil pH, with immediate reaction occurring after application. The dose indicated by the study is 7.2 g of the product in 500 g of soil. Elemental sulfur has a slow reaction, and its application proved to be unfeasible for soil acidification under the studied conditions. Therefore, further research with this source at higher doses and in different soil and environmental conditions is important so that more conclusive answers can be obtained regarding the use of elemental sulfur.

Authors' Contribution

Angélica Cristina Fernandes Deus: statistical analysis and writing - original draft preparation. Antônio Carlos Vargas Motta: soil collection, supervision and article writing. Eduardo Kieras Gugelmin: soil preparation, laboratory analysis and writing. Rodrigo Dal Pizzol: soil preparation, laboratory analysis, data tabulation. Simone Malinoski: soil preparation, laboratory analysis, data tabulation. Cibelle de Oliveira: laboratory analysis, data tabulation.

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