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SOIL SCIENCE

Potassium chloride: impacts on soil microbial activity and nitrogen mineralization

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ABSTRACT: *Potassium chloride is the most widely used potassium source worldwide, and due to its continuous use, the accumulation of its salts in the soil and in plants is becoming more common. Excess available ions can cause a series of physiological disturbances in organisms and can become a biocide in the soil. The objective of this study was to evaluate the effects of the application of KCl and banana crop residues on soil chloride content, microbial activity, and soil ammonification. The experiment utilized a completely randomized 2 × 4 factorial design with four replicates. Treatments were as follows: two doses of vegetal residue (200 and 400 mg dm^{-3}) × four doses of KCl (0, 167, 334, and 668 mg dm^{-3} of KCl) and a control (untreated soil). The CO_2 emission, ammonium ($N\text{-}NH_4^+$) and soil chloride (Cl^-) content, and mineralization/immobilization rates of the soils in each treatment were measured 4, 45, and 130 days after incubation (dai). Higher KCl dosages reduced soil microbial activity at 4 dai, regardless of the residue dosage. Microbial activity was reduced at 130 dai in all treatments when compared to the initial period. Higher dosages of banana crop residues increased the Cl^- content of the soil and promoted the immobilization of $N\text{-}NH_4^+$. We concluded that dosages of KCl (above 400 mg dm^{-3}), when applied to soils that already contain crop residues, reduce microbial activity and mineralization of N in the soil.*
Key words: *respirometry, salinity, bananeira residues, ammonification.*

Uso de cloreto de potássio: impacto na atividade microbiana do solo e mineralização do nitrogênio

RESUMO: *O cloreto de potássio (KCl) é a fonte de potássio mais utilizada mundialmente e, devido ao uso contínuo desse fertilizante, pode ocorrer acúmulo de sais no solo e nas plantas. O excesso de íons desencadeia uma série de distúrbios fisiológicos, tornando-se um potencial biocida no solo. Objetivou-se avaliar o efeito da aplicação de doses de KCl* e de resíduos culturais da bananeira no teor de cloreto do solo, na atividade microbiana e na amonificação. *O delineamento experimental foi inteiramente casualizado com quatro repetições. Os tratamentos foram arranjados em um fatorial 2 x 4: 2 doses de resíduo vegetal (200 e 400 mg dm^{-3}) x 4 doses de KCl (0, 167, 334 e 668 mg dm^{-3}), além de um controle (sem aplicação de KCl e resíduo). Foram quantificados o CO_2, o teor de amônio ($N\text{-}NH_4^+$) e de cloreto (Cl^-) do solo e as taxas de mineralização/imobilização, aos 4, 45 e 130 dias após a incubação (dai). O aumento da dose de KCl reduziu a atividade microbiana, aos 4 dai, independentemente da dose de resíduo adicionada. A atividade microbiana diminuiu, aos 130 dai: em todos os tratamentos, quando comparados ao período inicial. O acréscimo das quantidades de resíduos culturais da bananeira aumentou o teor de Cl^- do solo e promoveu a imobilização do $N\text{-}NH_4^+$. Conclui-se que doses de KCl maiores que 400 mg dm^{-3}, associadas a presença desse resíduo, reduzem a atividade microbiana e a mineralização do N do solo.*
Palavras-chave: *respirometria, salinidade, resíduos de bananeira, amonificação.*

INTRODUCTION

Banana (*Musa* sp.) is a socioeconomically important crop and is the most produced fruit in the world, with 107 million tons being produced worldwide per annum. Brazil is the third-largest producer of Banana, producing 7 million tons per year in an area of 461 thousand hectares (IBGE, 2018). However, crop productivity in Brazil is still considered low, particularly in the Northeast, where average annual Banana production is of 14 t ha^{-1}. Among the causes of this low productivity are the scarcity of rainfall and the inadequate management of fertilization and irrigation.

Banana requires a large amount of nutrient input to produce high yields due to the large amount of vegetal mass produced. Potassium (K) is the most required nutrient during the growth of Banana of the total macronutrients absorbed (BORGES et al., 2015). In Brazil, the amount of

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K recommended for adequate banana cultivation varies from 450 to 700 kg ha^{-1} of K_2O (SILVA, 2015) and, according to SILVA; BORGES & MALBURG (1999), the of dosage K_2O is commonly higher in other countries, reaching values up to 1200 kg ha^{-1} year^{-1} (2,000 kg ha^{-1} KCl).

Potassium chloride (KCl) is the most widely-used K source worldwide (SILVA, 2011). However, the accumulation of ions in the soil due to fertilizer application can result in large increases in soil salinity, damaging the plants and other organisms present in the soil (VIEIRA-MEGDA et al., 2014).

The leaf litter resulting from the cultivation of bananas contains high amounts of nutrients that can be absorbed by plants and should be considered when designing fertilization programs (BORGES et al., 2015). In a study by HOFFMANN et al. (2010), K was the macronutrient which was accumulated to the greatest extent in plants. The authors concluded that 14-37% of accumulated K was exported via bulk transport, with the remainder being deposited in the soil.

Effects of the excessive accumulation of soluble salts on plants and microorganisms can be amplified by poor water absorption, inducing water stress. This amplification if facilitated by the toxicity of specific ions such as Cl^- and by the interference of salts in physiological processes (RIETZ & HAYNES, 2003). Excess Cl^- in the protoplasm disrupts cell function, affecting the respiratory chain, N uptake, and protein metabolism (LARCHER, 2000; MUNNS, 2002). Increases in salt concentrations; therefore, have detrimental effects on biological processes occurring in the soil (INTRASUNGKHA et al., 1999; PANSWAD & ANAN, 1999).

Several studies in the laboratory and in the field have shown that Cl^- ions, even in low concentrations, can inhibit important processes such as ammonification and nitrification in the soil (SOURI, 2010; VIEIRA-MEGDA et al., 2014 and 2015; MARIANO et al., 2016). Thus, the evaluation of the microbial activity in saline soils is of great relevance, being helpful in the management of the potassic fertilization and improving the quality of the soil and overall productivity.

Based on the above, we hypothesized that excess Cl^-, when added to the soil through potassium fertilization with KCl or through the decomposition of plant residues, has a biocidal effect, reducing soil microbial activity and inhibiting nitrogen cycling in the soil. The objective of this study was to evaluate soil Cl^- content and its effects on microbial activity and N mineralization as a function of the application of KCl and banana crop residues.

MATERIALS AND METHODS

The experiment was conducted under aerobic incubation conditions over a period of 130 days. The experimental design was completely randomized, included four replicates, and consisted of a factorial 2 x 4 design with the following treatments: two doses of banana residue [200 (R1) and 400 (R2) mg dm^{-3}] corresponding to dosages of 7.5 and 15 t ha^{-1}, respectively, and four doses of KCl [0 (0), 167 (1), 334 (2) and 668 (3) mg dm^{-3}], and a control plot (without the application of either vegetal residue or KCl).

Vegetal residue was collected from 4-year-old banana plants (‘Prata Anã’ variety) which had been fertilized according to the recommendations for the culture (SOUZA et al., 1999). After collection, the residues were placed in an oven at 65 ºC where they were dried to a constant mass and then passed through a Wiley mill (30 mesh). The macronutrient concentrations of the dry matter were determined and were as follows: N (7.3 g kg^{-1}), P (0.7 g kg^{-1}), K (3.4 g kg^{-1}), S (0.8 g kg^{-1}), Ca (18.9 g kg^{-1}), Mg (3.1 g kg^{-1}); and micronutrients: B (19.6 mg kg^{-1}), Cu (3.45 mg kg^{-1}), Fe (1212.5 mg kg^{-1}), Mn (204.8 mg kg^{-1}), Zn (18.6 mg kg^{-1}), and Cl (88 g kg^{-1}) according to the methodologies described in MALAVOLTA et al. (1997). The C/N ratio of the residue was 9.

The soil, classified as an Oxisol, was collected from the 0 to 0.2 m layer in a preserved forest (soil which had not previously been managed and had low K content) in the Cerrado area. This was then de-routed, air dried, and passed through a 2 mm mesh sieve. The following chemical attributes of the soil were analyzed according to the methodologies described in EMBRAPA (1997): pH of soil water (4.0), organic matter–colorimetric method (2.7 dag dm^{-3}), phosphorus (0.6 mg dm^{-3}) and K content (35 mg dm^{-3}) measured using Mehlich 1, calcium (0.5 $cmol_c$ dm^{-3}), magnesium (0.2 $cmol_c$ dm^{-3}), H + Al (12 $cmol_c$ dm^{-3}), Aluminum content (0.9 $cmol_c$ dm^{-3}) - extracted with KCl 1 mol L^{-1}, CTC_7 (12.9 $cmol_c$ dm^{-3}), B-$CaCl_2$ (0.2 mg dm^{-3}), Cu^{+2} (0.2 mg dm^{-3}), Fe^{+2} (73.8 mg dm^{-3}), Mn^{+2} (4.9 mg dm^{-3}) and Zn^{+2} content (1.1 mg dm^{-3}) measured using Mehlich-1, and sand (34 dag kg^{-1}), silt (2 dag kg^{-1}), and clay (64 dag kg^{-1}).

The dosages of K were based on the K content considered suitable for growing bananas–120 mg dm^{-3} of K (SOUZA et al., 1999) considering the soil content (35 mg dm^{-3}) and corresponding to dosages of 300 kg ha^{-1} of K_2O. As a result, the dosages were setup to reflect dosages of 200-800 kg ha^{-1} of K_2O.

Experimental units were composed of 300 ml plastic containers containing 50 g of air-dried fine earth. To correct for the inherent soil acidity, calcium carbonate was applied to the soils with the aim of increasing the soil's saturation to 70%. 8 g of water was also added to maintain the maximum soil water retention capacity (CMRA) at 50%, according to the methods of BREMNER & SHAW (1958). The soil was then pre incubated under aerobic conditions for 20 days to reactivate microbial biomass. Phosphate fertilizer (triple superphosphate) was applied at a dosage equivalent to 120 kg ha^{-1} of P_2O_5. Mineral N was not applied considering that one of the objectives of the study was to estimate the mineralization of N.

After the pre-incubation period, the treatments were diluted with distilled water and applied superficially to banana residues and incorporated into the soil in order to raise the soil moisture to 70% CMRA and maintain the conditions considered adequate for soil organisms. The respirometry and N-NH_4^+ and Cl^- content of the soil was measured at 4 and 130 days after incubation (dai) and mineralization/immobilization was estimated at 4, 45, and 130 dai.

Quantification of the evolved CO_2 (mineralizable C) was performed using the respirometry technique of CURL & RODRIGUEZ-KABANA (1972) and STOTZKY (1965). Soil samples were conditioned in plastic containers and hermetically sealed at room temperature (27 °C ± 0.6). Thirty milliliters of 0.5 M NaOH was added to capture the CO_2 released by the respiration of heterotrophic microorganisms.

Extraction of N-NH_4^+ was carried out according to the methodology of CANTARELLA & TRIVELIN (2001) with a solution of KCl 2.0 mol L^{-1} in the ratio of 1:5 (soil:solution). The N-NH_4^+ was quantified by steam distillation. Cl^- was extracted in an aqueous solution and titrated with $AgNO_3$ in the presence of K-chromato as an indicator (EMBRAPA, 1997). Using the difference between the N-NH_4^+ content reported in each treatment and the control (soil only), it was possible to estimate the nutrient content derived from the mineralization (ammonification) or immobilization of native soil N at each measurement interval (4, 45 and 130 dai).

The normality of the data was verified by the Shapiro-Wilk (W) test with significance set at 5% probability. Analyses were performed using the statistical analysis software R. Analysis of variance (ANOVA) was used to examine the data using the F test. The Tukey test ($p<0.05$) was used to detect significant causes of variation in relation to the residual interaction x KCl. Regression analysis was used to identify meaningful interactions caused by variation in KCl dosage (assuming constant residue dosage) based on results of the ANOVA and coefficient t tests.

RESULTS AND DISCUSSION

The interaction KCl × residue had a significant effect on soil microbial activity at day 4 and 130 (Figures 1 and 2). Increasing KCl dosage reduced microbial activity at day 4, with the KCl 1 treatment

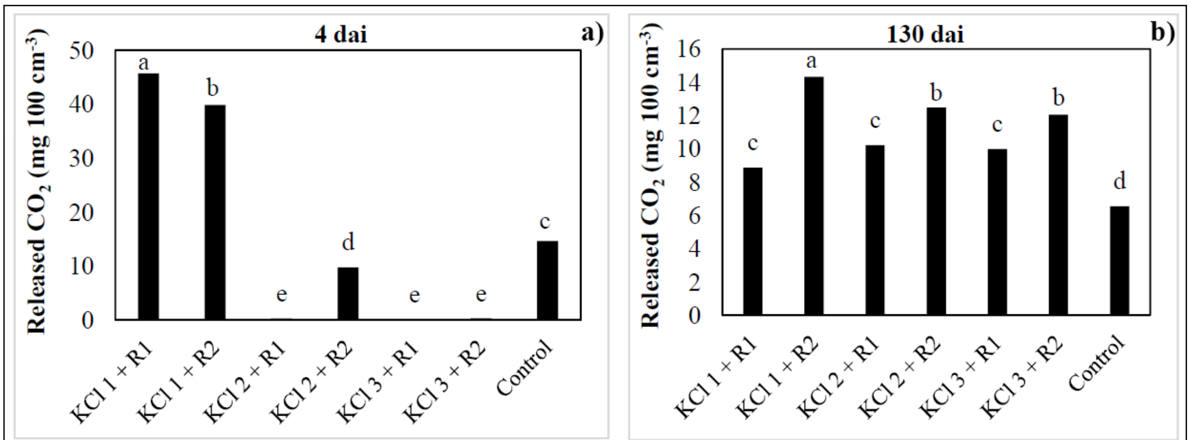


Figure 1 - Effect of potassium chloride (KCl) associated to doses of bananeira residue on soil microbial activity at 4 (a) and 130 (b) days after incubation (dai). The KCl 1, KCl 2 and KCl 3: 167, 334 and 668 mg dm^{-3} of KCl, respectively. The R1 and R2: 200 and 400 mg dm^{-3} of residue, respectively. Control: without KCl and residue application.

releasing the most CO_2 (52.2 mg), regardless of the residue dosage used (Figure 1a). Microbial activity in the control was equal to or greater than in the KCl 2 and KCl 3 treatments at both residue dosages, highlighting the antagonistic effect of the application of high dosages of KCl.

At day 4, we observed variable increases in emitted CO_2 in the KCl 1 + R1 and KCl 1 + R2 treatments based on residue dosage (Figure 1a). This result suggested that excessive increases in the amount of labile organic C from banana residues (C/N equals 9) in the soil had no positive effect on the activity of soil microorganisms during the initial period. The significance of the KCl x residue interaction is primarily due to the fact that banana residue has a high nutrient content, and that after decomposition and mineralization, nutrients are readily available in the soil solution and are absorbed by plants and microorganisms (HOFFMANN et al., 2010). By analyzing the residue, we reported that the concentration of Cl was very high (88 g kg^{-1}), which initially caused a toxic effect in soil microorganisms.

Considering the absolute values of CO_2 release at 130 dai (Figure 1b), a reduction in microbial activity was observed in all treatments (relative to values from 4 dai; Figure 1a). CO_2 release was, on average, 50 mg 100 cm^{-3} soil at 4 dai and 14 mg 100 cm^{-3} at 130 dai, indicating that over time the harmful effects of excess salts in the soil increased. This result also suggests the possible exhaustion of labile C substrata. However, at 130 dai (Figure 2b) the treatment with a residue dosage of 400 mg dm^{-3} promoted higher CO_2 emissions from the soil, suggesting higher microbial activity. The high amount of C in the soil in treatments with the highest residue dosages likely facilitated the survival of soil microbes by providing them an additional energy source (KAISER et al., 1995). In addition, greater soil microbial activity was observed in the latter period of the experiment and associated with higher K dosages, possibly due to the adaptive capacity of the soil microbiota.

VIEIRA-MEGDA et al. (2014) stated that the soil microbiota can become resilient to the negative effects of certain soil conditions. This is due to the ability of microorganisms to rapidly adapt to their environment, as demonstrated by the observed increase in microbial respiration at 130 dai with increasing doses of KCl.

According to other studies, the salinity tolerance limit of organisms depends on the concentration of salt in the soil solution, exposure duration, and the stage of development of affected the plants and microorganisms, with the initial stages of exposure being the most critical (SANTANA et al., 2007; VIEIRA-MEGDA et al., 2014 and 2015). SÁNCHEZ et al. (2004) evaluated the induced inhibition of nitrification by Cl^- ions, reporting low NH_4^+ and nitrite oxidation rates after the application of 70 g L^{-1} of NaCl. However, the oxidative capacity of soil microorganisms later recovered, demonstrating the resilience of soil microorganisms when placed under adverse conditions.

In relation to soil N-NH_4^+ content, higher residue dosages were associated with reductions in N-NH_4^+ content (Figure 2), possibly due to more

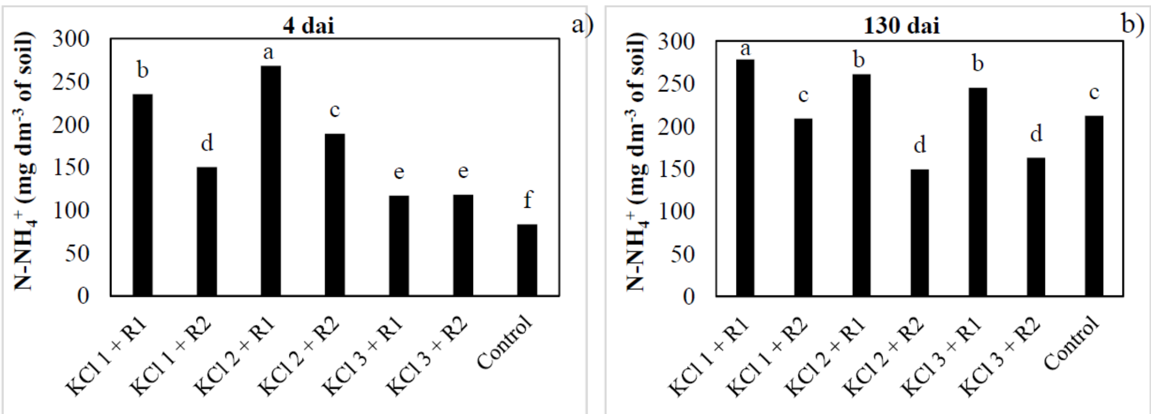


Figure 2 - Effect of potassium chloride (KCl) associated to doses of bananeira residue in the N-ammonium of soil at 4 (a) and 130 (b) days after incubation (dai). The KCl 1, KCl 2 and KCl 3: 167, 334 and 668 mg dm^{-3} of KCl, respectively. The R1 and R2: 200 and 400 mg dm^{-3} of residue, respectively. Control: without KCl and residue application.

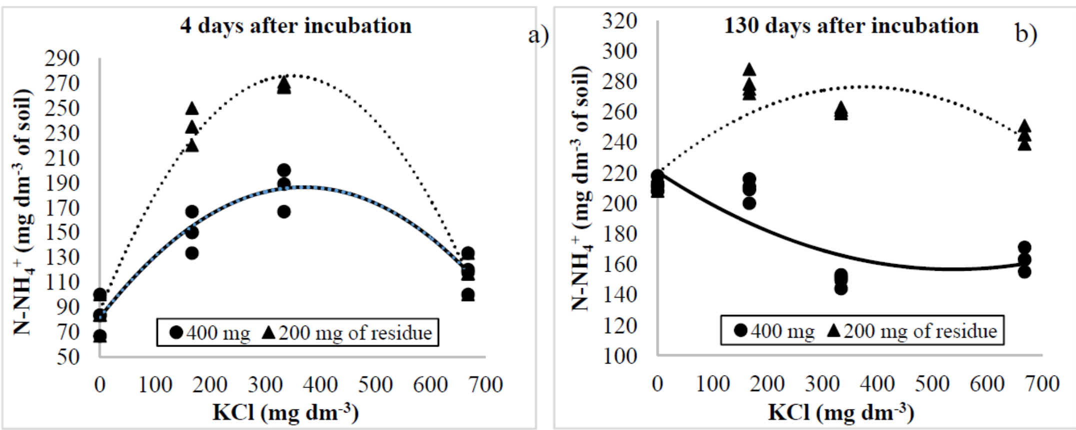
efficient N absorption caused by the higher biomass and carbon content of the soil. SOUZA et al. (2006) evaluated the effects of different soil systems and uses on the fractions of microbial activity and organic carbon present in oxisols, finding that (relative to an area used in conventional tulip cultivation) the soils of the Cerrado area contained three times more carbon of the light fraction (CFL) and; consequently, exhibited greater microbial activity. According to the authors, the high carbon content of the soils in native Cerrado is caused by the increased input of organic residues into the soil due to more abundant leaf litter and higher rhizo deposition. Heightened soil carbon content is also facilitated by the low-intensity decomposition occurring in more rural areas away from the influence of human activity.

Commonly, the exchangeable nutrient content of the soil is used as the basis upon which K application recommendations are made. However, K, as well as other nutrients, may already be available in the soil as a result of the mineralization of plant residues deposited on the surface (SIMONSSON et al., 2007). CATTELAN et al. (1997) concluded that microbial development was stimulated by increased organic carbon and soil water availability. According to GERALDES et al. (1995), in addition to the difference in microbial biomass occurring between different preparation systems, there is a seasonal variation of the microbial biomass, which is a direct relation between the increase in the population of the microbial biomass with the availability of nutrients from the litter and the increase of soil moisture at the beginning of the rainy season.

The average N-NH_4^+ content in the soil increased with time, with values of 155 mg dm^{-3} at day 4 and 210 mg dm^{-3} at day 130 (Figures 2a and 2b). In this same period, a decrease in the CO_2 released because of microbial activity (Figure 1B) was observed, which may be related to the higher availability of N, that is, with lower microbial activity in the soil, nutritional needs are reduced.

Increase in soil C availability through the addition of organic residues can immediately stimulate microbial activity and is known as the priming effect (AZAM & IFZAL., 2006). In addition, the reduction in microbial growth due to several factors, such as excess salts and water scarcity, may reduce biomass and nutritional demand for nutrients (GRAHAM et al., 2002).

In relation to the interactions K x residue for the net content of N-NH_4^+, there was an influence of the KCl doses, according to the model of the equations shown in figure 3. At day 4, the quadratic effect of the N-NH_4^+ content was observed as a function of the KCl doses associated with the addition of banana plant residues ($p \leq 0.01$) (Figure 3a). Doses that provided the highest levels of N-NH_4^+ in the soil (274.4 and 188 mg dm^{-3}) were 206.3 and 225.1 mg dm^{-3} KCl with a dose of 200 and 400 mg dm^{-3} of residue, respectively, with a depressant effect on the net content of NH_4^+ from that dose (Figure 3a).



$Y_{200} = -0.0044x^2 + 1.8155x + 87.079 \quad R^2 = 0.98^{***}$

$Y_{400} = -0.0021x^2 + 0.9456x + 81.545 \quad R^2 = 0.90^{***}$

$Y_{200} = -0.0004x^2 + 0.301x + 219.66 \quad R^2 = 0.70^{***}$

$Y_{400} = 0.0002x^2 - 0.2376x + 220.57 \quad R^2 = 0.80^{***}$

Figure 3 - Effect of potassium chloride (KCl) associated to doses of bananeira residue in the ammonium of soil (N-NH_4^+) at 4 (a) and 130 (b) days after incubation with treatments.

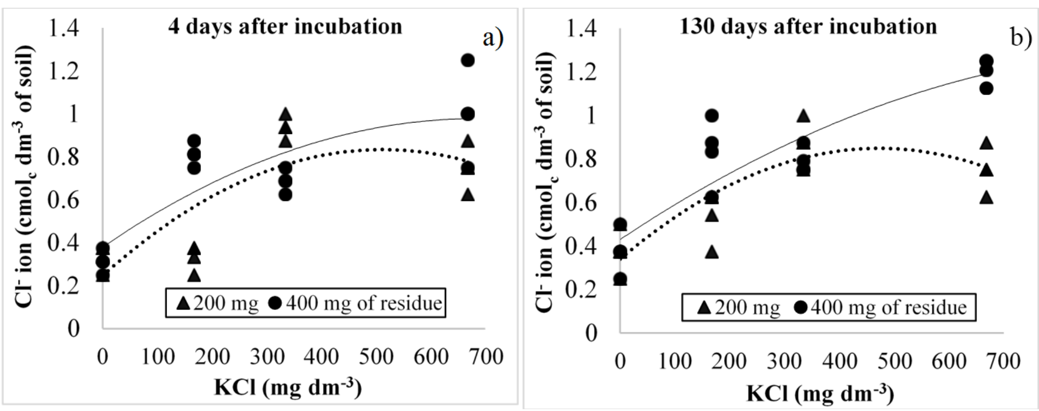
At day 130, the dose that provided the maximum content of $N\text{-}NH_4^+$ in the soil (276.3 mg dm^{-3}) was 375 mg dm^{-3} of KCl associated with 200 mg dm^{-3} of residue. In relation to the higher residue dose, a reduction in $N\text{-}NH_4^+$ levels was observed with increasing KCl doses. These results demonstrated the deleterious effect caused by the excessive use of potassium fertilizer on the production of $N\text{-}NH_4^+$, mainly owing to the reduction in microbial activity. It is aggravated by the fact that banana is a perennial crop with continuous addition of saline fertilizers, such as KCl, which can lead to the accumulation of salts in the soil, mainly in semi-arid or arid regions, where banana is irrigated by drip irrigation or micro aspersion. High concentrations of Cl^- in the residue remain free in the cell, being easily part of the soil-plant system and when in excess, can form oxidative compounds, which degrade the cells, resulting in death of soil microorganisms (CHEN & WONG, 2004; CHRISTENSEN et al., 1981).

The increase of the KCl doses promoted an increase in the available Cl^- content in the soil solution for both evaluated periods (Figure 4). It is worth mentioning that the higher dose of applied residue promoted greater availability of Cl^- content for absorption by the microorganisms. Saline stress can also reduce the absorption and transport of essential elements for the development and growth of plants and soil organisms, causing a nutritional imbalance that is an important component of salt stress. According to MARSCHNER (1997), Cl^- is the most toxic anion, and Na^+ is the most damaging cation in plant metabolism.

High concentrations of salts have negative effects on several bacterial groups responsible for nitrification, directly influencing the organic matter and N cycle (INTRASUNGKHA et al., 1999). In a study carried out by PANSWAD & ANAN (1999), the authors verified that a gradual increase of 0 to 18 g L^{-1} of Cl^- resulted in losses of nitrifying activity of 33 to 55% and, according to these authors, the effect is due to the high reactivity of chlorinated compounds, responsible for the oxidative action of organic matter, as it diffuses easily through cell walls of microorganisms and reacts with cellular proteins, oxidizing active points essential to cellular respiration, destroying vital structures, and thus causing their death (MCGUIRE et al., 1999).

The increase in soil KCl had a positive effect on the microbial activity at 130 day to the doses of 422 and 429 mg dm^{-3} and with 200 and 400 mg of residue, respectively (Figure 5a). Similar results were reported by VIEIRA-MEGDA et al. (2014), when studying the effect of NH_4Cl on nitrification and C of microbial biomass. Other authors also reported similar results when studying the application of high levels of salts in the soil, which directly affected the biochemical processes of plants and soil biotics (PENNES & CALLAWAY, 1992; MUNSTERS & TERMAAT, 1986).

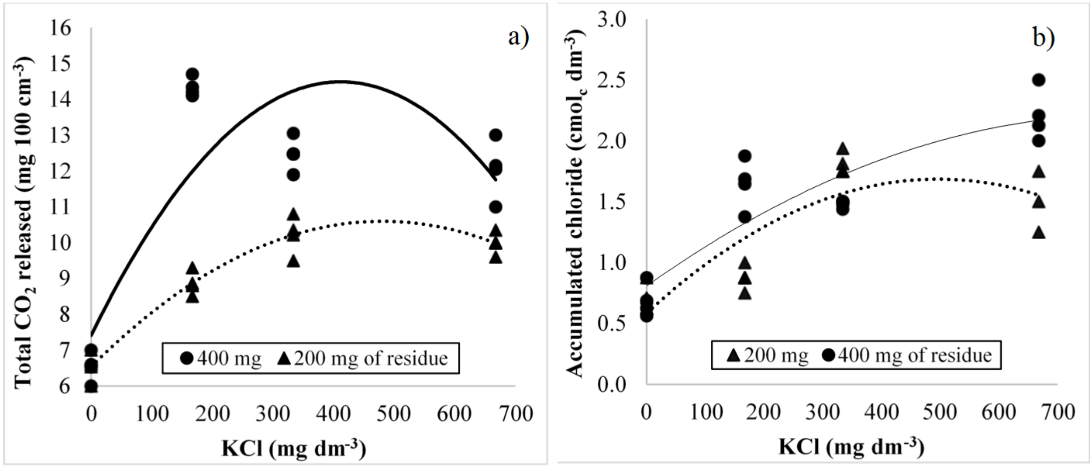
At day 4, treatments with higher doses of organic residues resulted in lower $N\text{-}NH_4^+$ yields in



$Y_{200} = -2E\text{-}06x^2 + 0.0023x + 0.2458 \quad R^2 = 0.63^{***}$
$Y_{400} = -1E\text{-}06x^2 + 0.0017x + 0.379 \quad R^2 = 0.69^{***}$

$Y_{200} = -2E\text{-}06x^2 + 0.0022x + 0.3398 \quad R^2 = 0.73^{***}$
$Y_{400} = -8E\text{-}07x^2 + 0.0017x + 0.4295 \quad R^2 = 0.82^{***}$

Figure 4 - Effect of potassium chloride (KCl) associated to doses of bananeira residue in the choride of soil (Cl^-) at 4 (a) and 130 (b) days after incubation with treatments.



$Y_{200} = -2E{-}05x^2 + 0.0169x + 6.5338$ $R^2 = 0.95^{***}$
$Y_{400} = -4E{-}05x^2 + 0.0343x + 7.4133$ $R^2 = 0.70^{***}$

$Y_{200} = -4E{-}06x^2 + 0.0044x + 0.586$ $R^2 = 0.72^{***}$
$Y_{400} = -2E{-}06x^2 + 0.0034x + 0.8085$ $R^2 = 0.80^{***}$

Figure 5 - Effect of potassium chloride (KCl) associated to doses of bananeira residue on microbial activity (a) and accumulated chloride (b) in the soil at 130 days after incubation with treatments.

the soil, on average 50 mg dm^{-3} less when compared to treatments where 200 mg dm^{-3} of plant residue was added (Table 1). These results suggested that the higher dosages of organic residue resulted in the lower mineralization of organic N and the greater immobilization of available N-NH_4^+ in the soil. Heightened organic matter decomposition in the early stages of the experiment caused by increases in the sizes of microbial populations in the soil promoted the temporary immobilization of nutrients (DIJKSTRA et al., 2004 and 2005; JANDL et al., 2007).

In addition, we found that when large amounts of residue are applied, available Cl^- accumulation is increased in the soil solution (Figure 5b). These results are reinforced by those presented in figures 3b and 5a, which illustrate that greater soil microbial activity was observed at day 130 and was associated with the higher immobilization of N-NH_4^+ and lower N-NH_4^+ liquid content in the solution. The highest net availability of N-NH_4^+ at the end of the experiment (130 dai) was observed in the treatment KCl 2+R1, in which the average N-NH_4^+ content was 300 mg dm^{-3}. Conversely, in the KCl

Table 1 - Ammonium content in the soil (N-NH_4^+) from mineralization (ammonification) or immobilization of soil nitrogen as function of the aplication of potassium chloride (KCl) and bananeira residues at 4, 45 e 130 days after incubation (day).

Treatment	------------------------------N-NH_4^+ (mg dm^{-3})-----------------------------			Liquid production of N-NH_4^+
	day 4	day 45	day 130	(mg dm^{-3})
KCl 1 + R1	100.0	22.2	70.0	192.2
KCl 1 + R2	50.0	133.3	0.0	183.3
KCl 2 + R1	166.7	83.3	50.0	300.0
KCl 2 + R2	100.0	116.7	-56.0	160.7
KCl 3 + R1	0.0	83.3	33.3	116.7
KCl 3 + R2	-33.3	-16.7	-33.3	-83.3

KCl 1, KCl 2 and KCl 3: 167, 334 and 668 mg dm^{-3} of KCl, respectively. R1 e R2: 200 and 400 mg dm^{-3} of banana residue, respectively. Negative values represent to imobilization of available inorganic nitrogen.

3+R2 treatment, N-NH_4^+immobilization was 83.3 mg dm^{-3}, leading to a N-NH_4^+ deficit in the soil solution (Table 1).

CONCLUSION

The accumulation of cultural banana residues in association with the application of KCl doses greater than 400 mg dm^{-3} reduces microbial activity in the soil, and this effect only intensifies over time.

Addition of KCl reduces the net ammonium content of the soil when applied at doses of 206 mg dm^{-3} or higher. Reduction is also associated with increases in the accumulation of vegetal banana residues in the soil, which increases the immobilization of native inorganic N in the soil.

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AUTHORS' CONTRIBUTIONS

All authors contributed equally for the conception and writing of the manuscript. All authors critically revised the manuscript and approved of the final version.

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