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CHANGES IN THE pH AND MACRONUTRIENTS IN SOIL FERTILIZED WITH HAIRY WOODROSE IN DIFFERENT AMOUNTS AND TIMES OF INCORPORATION[1]

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ABSTRACT – Organic fertilizing promotes changes in the physical, chemical and biological attributes of soil making it more productive. The objective of this study was to evaluate the effect of different amounts of hairy woodrose (*Merremia aegyptia* L.) and their times of incorporation on the chemical attributes of an Alfissol Eutrophic cultivated with lettuce. The experiment was conducted from April to June 2006 at the Universidade Federal Rural do Semi-Árido (UFERSA) in Mossoró-RN. The experimental design was complete randomized blocks with treatments arranged in a 4 x 4 factorial with 3 replications. The first factor consisted of four amounts of hairy woodrose incorporated into the soil (2.2, 4.4, 6.6 and 8.8 t ha^{-1} dry matter) and the second factor was the four times of their incorporations (0, 10, 20 and 30 days before transplanting lettuce). The soil pH remained alkali, decreasing with the amounts of hairy woodrose incorporated into the soil and with the times of incorporation. The contents of N, Ca and Mg in the soil increased with increasing amounts of hairy woodrose and with the times of incorporation in soil. The levels of available P and K increased with increasing amounts of hairy woodrose incorporated into the soil. However, in relation to the incorporation times, they were optimized at 16 and 14 days, respectively, after the manure incorporation. The utilization of hairy woodrose as organic fertilizer, generally, indicated improvement in soil chemical attributes in relation to the original values evaluated before its incorporation.

Keywords: *Merremia aegyptia*. Nutrient cycling. Organic fertilizing. Soil fertility.

ALTERAÇÕES NO pH E NOS MACRONUTRIENTES EM SOLO FERTILIZADO COM JITIRANA EM DIFERENTES QUANTIDADES E TEMPOS DE INCORPORAÇÃO

RESUMO - Adubação orgânica promove alteração nas propriedades físicas, químicas e biológicas do solo tornando-o mais produtivo. O presente trabalho teve como objetivo avaliar o efeito de diferentes quantidades de jitirana (*Merremia aegyptia* L.) e de seus tempos de incorporação nos atributos químicos de um Argissolo Vermelho Amarelo Eutrófico cultivado com alface. O experimento foi conduzido de abril a junho de 2006 na Universidade Federal Rural do Semi-Árido (UFERSA), Mossoró-RN. O delineamento experimental foi em blocos completos casualizados com os tratamentos arranjados em esquema fatorial 4 x 4, com 3 repetições. O primeiro fator consistiu de quatro quantidades de jitirana incorporadas ao solo (2,2; 4,4; 6,6 e 8,8 t ha^{-1} de matéria seca) e o segundo fator de quatro tempos de suas incorporações (0; 10; 20 e 30 dias antes do transplantio da alface). O pH do solo permaneceu alcalino, diminuindo com as quantidades de jitirana incorporadas ao solo e com os tempos de incorporação. Os teores de N, Ca e Mg no solo aumentaram com as quantidades de jitirana e com os tempos de incorporação no solo. Os teores de K e P disponível aumentaram com as quantidades de jitirana incorporadas ao solo. Porém, em relação aos tempos de incorporação, os teores desses nutrientes foram otimizados aos 16 e 14 dias, respectivamente, após a incorporação do adubo. A utilização de jitirana como fertilizante orgânico, de maneira geral, indicou melhoria nos atributos químicos do solo em relação aos valores originais avaliados antes da sua incorporação.

Palavras-chaves: *Merremia aegyptia.* Ciclagem de nutrientes. Adubação orgânica. Fertilidade do solo.

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INTRODUCTION

The soils of the tropics are predominantly characterized by natural low fertility, mainly due to low levels of organic matter and by the limitation of available phosphorus. The use of synthetic fertilizers in addition to their high costs has effects impacting to the soil and the environment. The organic wastes produced by industry, by the cities or the rural farm, now have larger importance as usable and recyclable materials, to improve soil conditions and increase its fertility level (TEDESCO et al., 1999).

The soil degradation process has as a consequence the low availability of nutrients and changes of the physical and biological properties that hinder the establishment and growth of plants (DIAS et al., 2007). The increase in the concentration of soil organic matter constitutes in the main benefit of the agricultural use of organic waste due to its contribution to the improvement in the chemical, physical and biological properties of soil (BERTON; VALADARES, 1991).

The use of green manure is a viable way to ease the impacts of modern agriculture, bringing sustainability to the agricultural soils. The effects promoted by green manure on soil chemical properties are quite variable, depending on factors such as the species used, the management given to biomass, the time of planting and the cut of green manure, the residence time of the waste on the ground, local conditions, and the interaction between these factors (ALCÂNTARA et al., 2000).

Among the effects of green manure on soil fertility is the increase of organic matter content, the greater availability of nutrients, the higher cation exchange capacity of the soil, the favoring of the production of organic acids, which besides favoring the solubilization minerals causes a decrease in the levels of exchangeable Al by its complexation and increase of the recycling capacity and mobilization of nutrients leached or poorly soluble that are in the deeper layers of the profile (CALEGARI et al., 1993).

The quality of the vegetable residue, particularly its C/N ratio and the lignin content and polyphenols affect the rate of N mineralization. Among the species used in green manure, the legumes stand out in forming symbiotic associations with N2-fixing bacteria and its low C/N ratio, coupled with the large presence of soluble compounds, favors rapid decomposition and mineralization, with a significant contribution of N to the soil-plant system (AITA et al., 2001; PERIN et al., 2004).

The mineralization rate of soil organic nitrogen is variable and is directly related to the labile character of the organic fractions and with the activity of the microbial groups that use and depend on factors such as temperature, moisture, aeration, amount and nature of the organic material present (CAMARGO et al., 1997).

There is great need to study the process of mineralization and release of nutrients of the biomass from spontaneous species. The knowledge of the dynamics of nutrients release is essential so that it can match the use maximum of these organic wastes in replacement to chemical fertilization.

The hairy woodrose is a plant native to Northeast region and very common during the rainy season. Some researches have been developed using this plant as green manure in the production of vegetables (GÓES, 2007; LIMA et al., 2008; LINHARES et al., 2009). According to these authors, the jitirana has characteristics that classify as promising for use as green manure, especially by high biomass production and nutrient concentration, and narrow C/N ratio, which results in rapid mineralization and release of nutrients.

The objective of this study was to evaluate the reaction of the soil and the availability of nutrients (N, P, K, Ca, Mg and Na) using hairy woodrose as organic fertilizer in different amounts and times of incorporation in a Eutrophic Alfissol cultivated with lettuce.

MATERIAL AND METHODS

The experiment was conducted in the period April to June 2006, in the experimental area of the of Plant Sciences Department at Universidade Federal Rural do Semi-Árido (UFERSA), Mossoró-RN. The soil was classified as Eutrophic Alfissol (EMBRAPA, 2006) with sandy loam texture with 84% sand, 11% silt and 5% clay. A soil sample was taken in the depth of 0-20 cm and subjected to a chemical analysis whose the results obtained were: pH (1:2.5 water) = 7.5, N_{total} = 0.64 g kg^{-1}, Ca^{2+} = 5.60 $cmol_c$ dm^{-3}, Mg^{2+} = 0.63 $cmol_c$ dm^{-3}, K^+ = 0.42 $cmol_c$ dm^{-3}, Na^+ = 0.44 $cmol_c$ dm^{-3}, Al^{3+} = 0.00 $cmol_c$ dm^{-3}, P = 5.0 mg dm^{-3} and CO = 7.45 g kg^{-1}. The pH analysis was performed using a potentiometer in the soil suspension with solution of 1:2.5 in water. The contents of Ca, Mg and Al were obtained by the extraction with KCl 1 mol L^{-1} and quantified by atomic absorption spectrophotometry and by titration with NaOH 0.01 mol L^{-1}, respectively. For P and K contents, the extractor used was the Mehlich solution (HCl 0.05 mol L^{-1} H2SO4 + 0.025 mol L^{-1}) and determined by calorimetry and flame photometry, respectively. The percentage of carbon was determined by dicromatometria and N_{total} by the Kjeldahl method.

The hairy woodrose used as organic fertilizer was collected in areas near the experimental area at the beginning of its flowering in the rainy season. The plants were ground in a conventional forage machine, obtaining particles from 2.0 to 3.0 cm, which were dried at room temperature until the moisture content reaches 10%, and then its chemical composition determined showing the following values:

27 g kg^{-1} N, 10 g kg^{-1} P, 10 g kg^{-1} K, 14 g kg^{-1} Mg and 12 g kg^{-1} Ca and C/N ratio of 18/1.

The experimental design was complete randomized blocks with the treatments arranged in a 4 x 4 factorial arrangement with 3 replications. Treatments consisted of a combination of four amounts of hairy woodrose incorporated into the soil (2.2, 4.4, 6.6 and 8.8 t ha^{-1} dry matter) and four times of incorporation (0, 10, 20 and 30 days before the lettuce transplanting). Each plot had a total area of 1.44 m^2 (1.20 m x 1.20 m) and a harvest area of 0.80 m^2 (1.00 m x 0.80 m).

The preparation of the soil of the experimental area consisted of a harrowing followed by the flowerbeds construction. The flowerbeds were subjected to solarization with transparent polyethylene Vulcabrilho Bril Fles (30 µm) for 45 days, to reduce the population of soil-borne pathogens. The incorporation of hairy woodrose was done manually every ten days. After the final incorporation of hairy woodrose (referring to 0 days of incorporation) and before planting of lettuce, three soil samples were taken at a depth of 0-20 cm in each plot to evaluate the following soil chemical attributes: pH, N_{total}, P, K^+, Ca^{2+}, Mg^{2+} and Na^+. The analysis of these attributes was performed as described above.

The data were subjected to the analysis of variance using the software SISVAR (FERREIRA, 2000). The fitting of response curves was prepared in function of the quantitative variables studied.

RESULTS AND DISCUSSION

There was no significant interaction between the amounts of hairy woodrose incorporated into the soil and its incorporation times on any soil attribute evaluated (Figures 1-6). However, the soil pH decreased with the amounts of hairy woodrose and with the times of soil incorporation. For every ton of hairy woodrose added to the soil and for each day that passed in the time of incorporation, was observed a decrease of approximately 0.05 and 0.33 in the pH values, ranging respectively from 7.6 to 7.3 and 7.6-7.3 (Figures 1A and 1B). The incorporation of organic fertilizer into the soil may raise or lower the pH of the soil, depending upon the predominance of the processes that consume or liberate H^+. The reduction of pH in alkaline soils in the presence of organic matter is due to the increase in the CO_2 concentration of the biological oxidation of organic compounds during the process of decomposition/ mineralization promoting the increase of organic acids, which react with water to form carboxylic acids, which dissociate to release protons (H^+) in the solution, reducing the pH of the soil. Another explanation for the reduction of the soil pH may also be attributed to the release of N and S, which upon being oxidized and react with the water, released H+ ions acidifying the soil (SOUSA et al., 2007).

According to Alvarez et al. (1999) a pH range between 7.1 and 7.8 is a weak alkaline reaction, as well as the soil reaction. However, from the agronomic point of view, the reaction of the soil is considered inadequate, since the suitable index of water pH varying in the range from 5.5 to 6.0, in which favors conditions to the plants absorb nutrients from the soil evenly (ALVAREZ et al., 1999). The reduction of soil pH with times of incorporation resulted from the greater release of H^+ ions in the soil solution, as a consequence of biological oxidation and processes of decomposition and mineralization of organic compounds added to the soil.

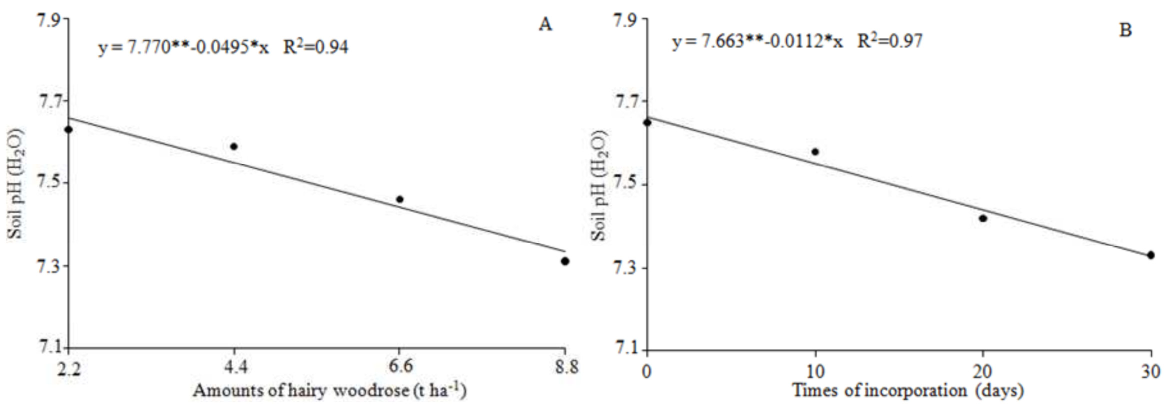

Figure 1. Soil pH in function of the amounts of hairy woodrose incorporated into the soil (A) and their times of incorporation (B).

It can be seen by the values of acidity (Figure 1) that the soil is highly alkaline, making unlikely the existence of Al^{3+} in the soil. The observed variation of pH 7.6 to 7.1 in water with the highest biomass amount of organic fertilizer and longer soil incorporation time, suggest that pH in saline solution is an attribute sensitive to the effects of low magnitude, typically associated with action of the own plants and soil management. These observations are corroborated by (POCKNEE; SUMNER, 1997). Under these conditions the rate of pH in water in a chemical and agronomic classification are considered high and inadequate alkalinity, respectively (ALVAREZ et al., 1999).

From the decreases of pH units obtained in relation to the amounts of hairy woodrose biomass and their times of incorporation into the soil is also observed the great importance of the incorporation of organic fertilizer evaluated under conditions of alkaline soils through a likely increased availability of micronutrients such as Fe, Cu, Mn and Zn. The pH index is one of the factors that affect the availability of these nutrients to the plants, promoting the insolubility of the same by forming oxides (MALAVOLTA, 1980; RAIJ, 1991). The increase of one pH unit decreases thousand times the concentration of Fe and one hundred times the concentration of Mn^{2+} in the soil solution (VALE et al., 1997). Thus, it is believed that the pH values achieved with increasing amounts of biomass and the times of incorporation of the organic fertilizer into the soil have been sufficient to promote increased availability of Cu^{2+}, Fe^{2+}, Mn^{2+}, and Zn^{2+} in solution soil.

Correa et al. (2005) evaluated the doses 0, 3.65, 10.95, 21.90, 43.80 and 87.60 t ha^{-1} on a dry basis of organic waste of processing industry of guavas on the chemical properties of an Ultisol Red-Yellow, observed that there was a slight and gradual reduction of pH values, proportional to the doses of residue incorporated into the soil, varying from 5.4 in the control treatment, to 5.1 in the dose of 44 g dm^{-3} (87.6 t ha^{-1} on dry basis), showing a slight acidification of the soil as a result of increasing levels of residue. Lacerda and Silva (2006) also observed a reduction of the pH in the soil with the use of jack bean as green manure. The influence of green manure improving the chemical properties of an Oxisol did not change the soil pH (BARROSO et al., 2008).

For the contents of total N in the soil, an upward linear equation was adjusted both with increasing amounts of hairy woodrose and with times of their incorporation evaluated into the soil. There were increases of 0.05 per ton added and 0,004 for each day in the time of incorporation, with the contents of total N ranging, respectively, from 0.52 to 0.88 and from 0.60 to 0.71 (Figures 2A and 2B). These results are explained by the chemical composition of hairy woodrose incorporated into soil, whose the content was of 27 g kg^{-1} N, which through the mineralization process or ammonification of organic N, liberated inorganic N in the soil in the ammonium form, where in the subsequent reactions occurred the conversion this form of N ammonium in N nitrate, the more absorbed form by plants. This explanation is due N be the main nutrient of the integral structure of organic molecules, where about 95% of N in the soil is attached to the carbon chain of soil organic matter and less than 5% of the total N is in inorganic forms such as ammonium ion (NH_4^+) and nitrate ions (NO_3^-) (SÁ, 1996).

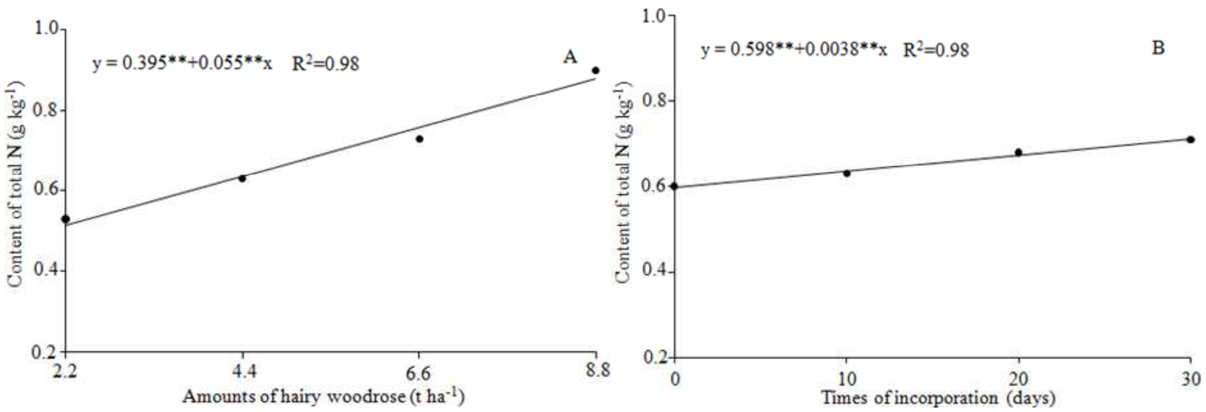

Figure 2. Content of total nitrogen (N) in function of the amounts of hairy woodrose incorporated into the soil (A) and their times of incorporation (B).

The large stock of N in the soil is in the organic form; after mineralization it is released in the form of inorganic N, constituting the main source of N for plants in many agricultural systems (CANTARELLA, 2007), as found in our study. In production systems with organic fertilization the total nitrogen is larger than in systems without fertilization or with mineral fertilizer only in the layers of 0-10 cm and 10-20 cm (LEITE et al., 2003). These authors also reported that the increase in the stock of total nitrogen in the systems receiving organic fertilization is associated with greater input of plant residues returned to the soil. Silva (2006) suggests that the accumulation of N in the soil, among other factors, depends on the input of organic residue in the soil, its quality with respect to the C/N, soil and climatic conditions, soil texture and water blade added to the soil through irrigation systems.

Regard to the P contents in the soil, an upward linear equation was adjusted with the amounts of hairy woodrose incorporated into the soil (Figure 3A) and a quadratic equation for P contents as a function of times of incorporation of hairy woodrose in the ground (Figure 3B). For each ton of green manure added, there was an increase of 0.34 in the P contents in the range from 7.33 to 9.60 mg dm^{-3}

(Figure 3A). On the other hand, the phosphorus contents increased with the times of incorporation until the maximum value of 9.37 mg dm^{-3} at the time of 16 days, decreasing then until the last amount of hairy woodrose added to the soil (Figure 3B). The increased contents of phosphorus with the amounts of hairy woodrose incorporated into the soil were a result of its concentration in the chemical composition (10 g kg^{-1}). Phosphorus is regarded as an integral part of organic molecules and suffers the process of decomposition and mineralization, mediated by soil microorganisms. The conversion of the forms of P organic to forms P inorganic available in the soil, besides increase the availability of soil P in condition of natural fertility, for foster greater dissemination of contents of P in the soil, due to the organic waste to reduce the soil density, increase the water content of the soil and favor greater and diverse microbial activity, such as the activities of arbuscular mycorrhizal fungi and phosphatase enzymes (MOREIRA; SIQUEIRA, 2002).

The soil to adsorb organic acids with great energy competes with the adsorption sites of P, increasing their availability in the soil by reducing the precipitation of phosphate ions (H_2PO_4) with Ca^{2+}. Another important aspect of the availability of organic P is the phosphatase enzyme activity, especially in the rhizosphere, due to his role on the degradation of organic phosphate compounds more quickly to the soil solution. It can still be explained by the rhizosphere acidification increasing phosphorus availability and due to a greater retention of Ca for the soil colloids with increasing soil CEC (LORENZ et al., 1994).

The P content of 9.60 mg dm^{-3} available in the soil with the maximum amount of 8.8 t ha^{-1} and the content of 9.37 mg dm^{-3} at 16 days of incorporation of hairy woodrose that is considered as very low by ALVAREZ et al. (1999). This is considered a very low concentration of available P (levels below or equal to 10.0 mg dm^{-3}) considering the clay content of the soil around 0-15%. Despite organic matter increase the cycling of P in soil, the organic management of soil assessed, was not efficient to increase the higher form of labile P in the soil. Probably the interaction between the phosphate ions and ions of Ca^{2+} in the soil sorptive complex becomes the P less available in soil.

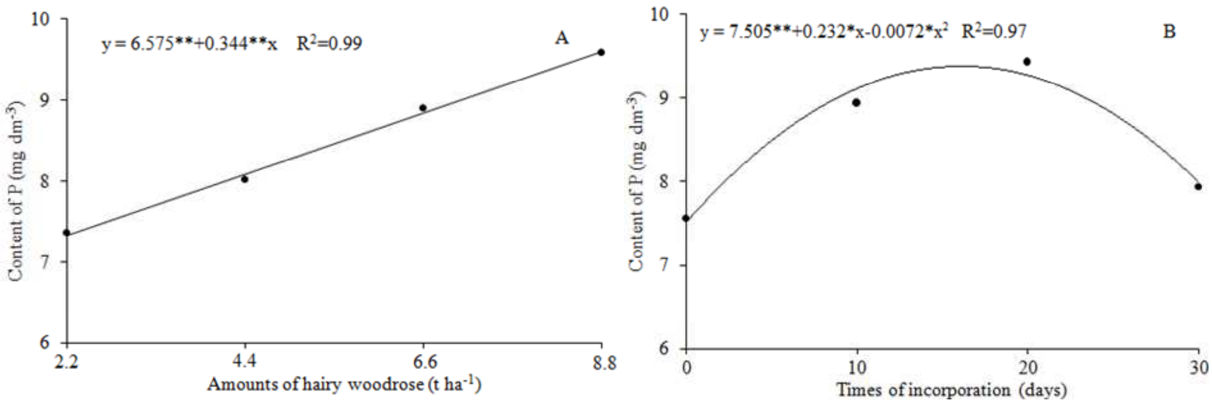

Figure 3. Content of phosphorus (P) in the soil in function of the amounts of hairy woodrose incorporated into the soil (A) and their times of incorporation (B).

The greater availability of soil P after 16 days of incorporation can also be explained by the rapid mineralization of organic compounds of hairy woodrose which has a low C/N. One possible explanation for the reduction in the P concentration with longer times of organic fertilizer incorporation into the soil from the point of maximum may be due to uniform distribution of the organic material in the soil profile with a rapid decomposition dependent of a greater contact surface disadvantaging the accumulation of nutrient in the organic fraction of the soil in which the soil in which the experiment was installed has no potential to adsorb organic acids occupying adsorption sites of phosphates, represented at semi-arid soil conditions by the increasing concentration of Ca^{2+} ions in the soil, thereby reducing the availability of P in the soil solution. These observations are corroborated by (BAYER; MIELNICZUK, 1999; ANDRADE et al., 2003.).

Silva et al. (2002) evaluating the effect of cover crops on P availability also found cycling and significant amounts of available P in soil with orange orchard-pear on intercropping of legumes. Boer et al. (2007) evaluating nutrient cycling by covering plants in cerrado soil, observed that the highest release rate of P occurred until 30 days after desiccation and varied among the species of plants evaluated.

The K contents was adjusted with a upward linear equation with the amounts of hairy woodrose incorporated into the soil (Figure 4A) and a quadratic equation for the K contents in function of times of incorporation of the hairy woodrose (Figure 4B). For each ton of green manure added, observed an increase of 0.05 in the K contents, in the range 0.68 to 1.01 $cmol_c$ dm^{-3} (Figure 4A). The K contents increased with the times of incorporation until the maximum value of 1.00 $cmol_c$ dm^{-3} at the time of 14 days, decreasing until to the last amount of hairy woodrose added to the soil (Figure 4B). The available K content of 1.01 $cmol_c$ dm^{-3} corresponds to 394.9 mg dm^{-3} in the soil sorptive complex in the presence of 8.8 t ha^{-1}. The content of 1.00 $cmol_c$ dm^{-3}, corresponding to 391.0 mg dm^{-3} obtained at 14 days of the hairy woodrose incorporation to the soil, is considered as very high (ALVAREZ et al., 1999).

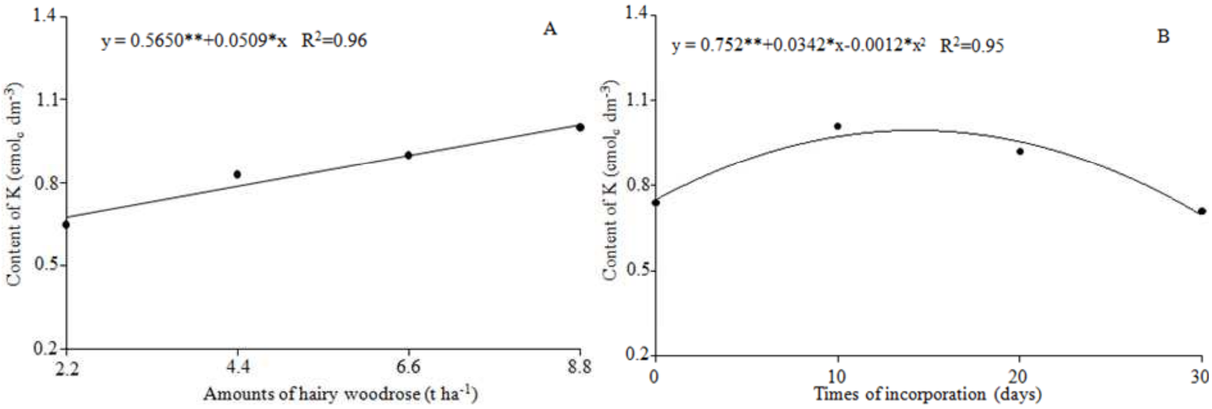

Figure 4. Content of potassium (K) in the soil in function of the amounts of hairy woodrose incorporated into the soil (A) and their times of incorporation (B).

Despite of K does not integrate to any stable organic compound, the increase of its concentration in the soil, with the addition of hairy woodrose, is not only the result of direct release but probably by increasing the exchange capacity of soil cations as well. Adsorbing ions K^+ to the negative charges of the surfaces of organic colloids by electrostatic binding, prevents thus their leaching, and with that resupplying the nutrient availability in the soil solution increases. It is also possible that the increase water content and the reduction of the soil density, have contributed to a greater diffusion of the exchangeable potassium in the soil. However, the reduction in availability of the K contents with the highest incorporation times of hairy woodrose may be explained by rapid liberation of K by the process of mineralization of the organic compounds. May also have occurred an interaction between the exchangeable potassium and the high concentration of exchangeable calcium in the soil. The release of K by organic residues in a greater proportion causes inhibition of the others elements. Such observation on the rapid release of K by the mineralization process is supported by the results found by GIACOMINI et al. (2000).

According to MALAVOLTA et al. (1989), K is the nutrient more readily released from the organic residues, because it is the element present in the plant tissues under the form ionic, but does not integrate to plants compounds. The increase of K in the soil with the use of leguminous plants as green manure has been reported by several authors (NASCIMENTO et al., 2003; LACERDA; SILVA, 2006; FARIA et al., 2007).

The increase in the N content released by hairy woodrose may be responsible for the leaching of K with the highest time of incorporation, in proportion that the nitrification occurs. The release of nitrate in sandy soil promotes a greater leaching of basic cations (K, Ca or Mg) required as accompanying ions, while the protons produced by nitrification of ammonium, and, or of organic N remain in the surface layer as a potential acidity influencing in the pH (HELYAR, 1991).

For contents of exchangeable calcium (Ca^{2+}), an upward linear equation was adjusted both for the amounts of hairy woodrose incorporated and times of incorporation of hairy woodrose in the ground (Figures 5A and 5B). For every ton of green manure added and for each day that passed in the time of incorporation, observed an increase of 0.21 and 0.12 in the contents of Ca^{2+}, in the range from 5.08 to 6.46 $cmol_c$ dm^{-3} between the lowest and highest amount of hairy woodrose and of 5.67 to 6.18 $cmol_c$ dm^{-3} between the lowest and highest time of incorporation (Figures 5A and 5B). The maximum contents Ca^{2+} obtained with the amount of 8.8 t ha^{-1} of hairy woodrose and with the incorporation time to the soil of 30 days were respectively 6.46 and 6.18 $cmol_c$ dm^{-3} (Figures 5A and 5B). The increase of 0.86 $cmol_c$ dm^{-3} of Ca^2+ in the soil sorptive complex resulted directly of the mineralization of the organic material incorporated to the soil, whose chemical composition showed 12 g kg^{-1} of Ca and by favoring also greater availability of Ca^{2+} adsorbed in the colloidals minerals of the soil. The dynamics of the exchangeable calcium in the soil is very simple and similar to the dynamics of the potassium and magnesium. They are considered ions competitors, since a higher concentration of one inhibits the availability of the other. However, calcium is more strongly adsorbed to organic and mineral colloids of tropical soils than the potassium and magnesium, for it is a divalent cation and with small radius of hydration. The connection of adsorption calcium to the organic colloids despite being electrostatic is more specific than for the cations potassium and magnesium, showing a less intense leaching. The Ca is the cation that has higher buffering with the organic colloids of the soil, due to its greater reaction with the negative charges of the functional groupings of the organic matter stabilized in the soil (MENDONÇA et al., 2006).

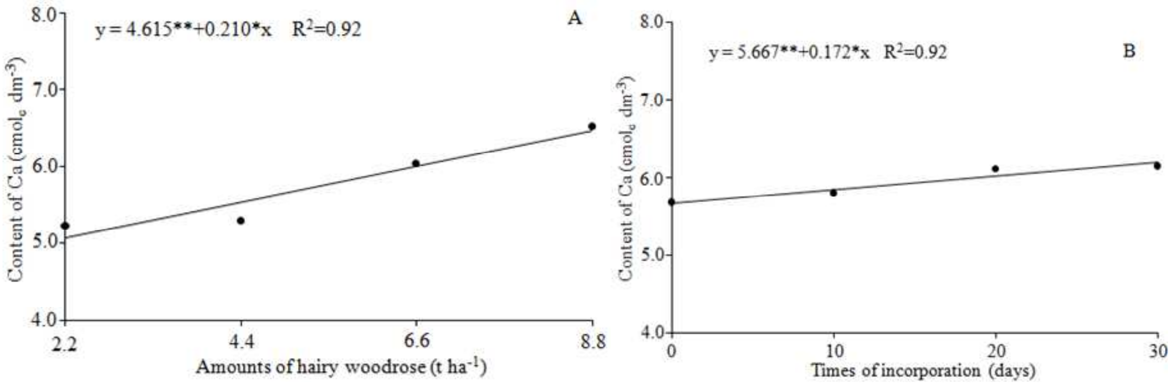

Figure 5. Content of calcium (Ca) in the soil in function of the amounts of hairy woodrose incorporated into the soil (A) and their times of incorporation (B).

The soil of the experimental area evaluated in natural fertility conditions showed high contents of Ca^{2+}, 5.60 $cmol_c$ dm^{-3}, which increased to 6.46 $cmol_c$ dm^{-3} with the incorporation of higher amount of hairy woodrose (ALVAREZ et al., 1999).

The use of legumes in vineyards of Petrolina-PE, in an Yellow Ultisol, after eight years resulted in the improvement in soil chemical characteristics, including increase in the exchangeable Ca^{2+} contents at 0-10 cm depth (FARIA et al., 2004). Similar results have been observed by others authors (SILVA et al., 2002; CENTURION et al., 2005) using different plant species as green manure, regardless the legumes were used in intercropping and with organic fertilizer in topdressing.

It was adjusted an upward linear equation for the contents of exchangeable magnesium (Mg^{2+}) both in function of amounts of incorporated hairy woodrose and for the incorporation times of hairy woodrose in the soil (Figures 6A and 6B). For every ton of green manure added to the soil and for each day that passed in the time of incorporation, there was an increase of 0.0372 and 0.0034, respectively, in levels of Mg^{2+} between the lowest and highest amount of hairy woodrose and between the lowest and highest incorporation time (Figures 6A and 6B). The Ca^{2+} maximum contents obtained with the amount of 8.8 t ha^{-1} of hairy woodrose and with the time of incorporation into the soil of 30 days were respectively of 0.718 and 0.646 $cmol_c$ dm^{-3} (Figures 6A and 6B). The increase of 0.016 $cmol_c$ dm^{-3} of exchangeable magnesium in the soil with the greater amount of hairy woodrose incorporated into the soil, was probably due to the release of Mg to the ground by the process of mineralization of organic compounds derived from wastes of the hairy woodrose, whose the contents of Mg in its chemical composition was 14 g kg^{-1} and probably by having favored a greater adsorption of exchangeable magnesium to the negative charges of the functional groups of the organic matter stabilized in the humus form, making impossible an intense leaching of this nutrient. Naturally, magnesium exchangeable content in the soil is less than the exchangeable calcium content of organic compounds due to the greater affinity of Ca be complexed to the negative charges of the surfaces of the organic colloids and minerals of the soil, representing thus, higher buffering capacity of the Ca for the organic colloids and minerals from the soil due to higher Ca reaction with the functional groups of the organic fraction than the K and Mg exchangeable (KHIEL, 1985; RAIJ, 1991).

The contents of exchangeable magnesium (Mg^{2+}) in the soil in condition of natural fertility and obtained with the incorporation of hairy woodrose to the soil are considered as medium, conform the concentration proposed by ALVAREZ et al. (1999), which consider a mean concentration of exchangeable magnesium with contents ranging from 0.46 to 0.90 $cmol_c$ dm^{-3}. Probably due to low soil CEC and low C:N ratio of the organic fertilizer, this increase in the contents of exchangeable magnesium with the incorporation time in the soil was due to the greater possibility of increasing the negative charges of the soil, increasing the buffering capacity of the soil adsorbing greater amounts of the nutrients available, avoiding its loss by leaching, besides promoting to the soil physical processes, for example, the reduction of the soil density and increase of the aggregation of the primary particles of the soil. It takes also into account the capacity of this spontaneous species of restituting magnesium to the ground through its biomass incorporated into the soil with the passage of time and also for favoring the activities of soil microorganisms (TRANI, 2003). The increase in the contents of calcium and magnesium exchangeable suggests that the incorporation of organic fertilizers to the soil promotes the reposition of the contents of these nutrients in the soil, favoring its fertility.

Alcântara et al. (2000) evaluating the soil chemical attributes, observed higher contents of available Mg in soils fertilized legumes pigeonpea and sunn hemp probably due to higher capacity of these legumes of returning Mg to the soil through their biomass incorporated into the soil.

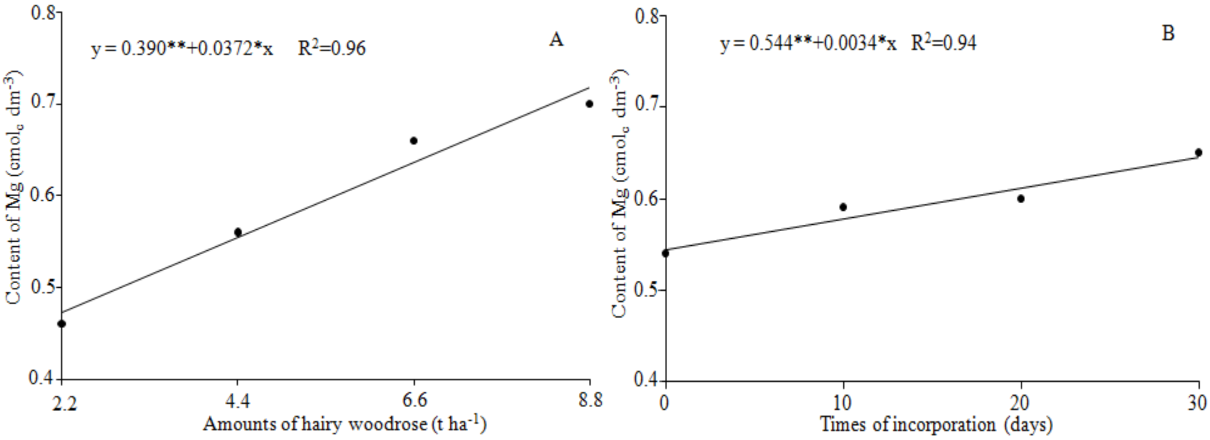

Figure 6. Content of magnesium (Mg) in the soil in function of the amounts of hairy woodrose incorporated into the soil (A) and their times of incorporation (B).

There was a reduction in exchangeable sodium content (Na^+), both with the amounts of hairy woodrose incorporated to the soil and with the times it was incorporated (Figures 7A and 7B). The higher complexity of the internal sphere of the Na ions to the organic colloids, as for example, the carboxylic and phenolic functional groups, promoting lower availability of Na ions, relative to exchangeable cations, K^+, Mg^{2+} and Ca^{2+} in function of the complexation by outer sphere of these ions. Another explanation may be due to higher concentration of ions K^+, Mg^{2+} and Ca^{2+} supplied to the soil by organic fertilizer, promoting greater competition from these ions by the adsorption sites of the colloids organic, thus favoring a higher leaching of the contents of Na ions in the soil, where the adsorption capacity obeys the following order: Al> Ca> Mg> K> Na (RAIJ, 1991).

It is possible that the low contents of exchangeable sodium adsorbed to the minerals colloids of the soil are responsible for the reduction in exchangeable sodium content.

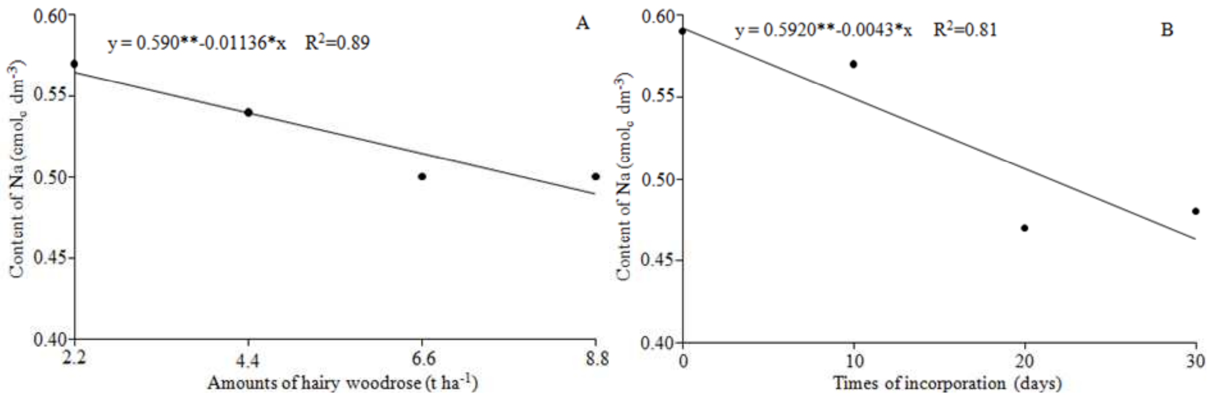

Figure 7. Content of sodium (Na) in the soil in function of the amounts of hairy woodrose incorporated into the soil (A) and their times of incorporation (B).

CONCLUSIONS

The use of hairy woodrose as organic fertilizer reduced the pH, but not enough to make the acid soil, however, favored the input of N, P, K, Ca and Mg. The incorporation times of the hairy woodrose into the soil most recommended for the higher amount of P and K were at 16 and 14 days. The use of hairy woodrose as organic fertilizer, promoted improvement in the soil chemical attributes in relation to the original attributes evaluated before its incorporation

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