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A N   I N T E R N A T I O N A L   J O U R N A L

A Laboratory Method to Estimate the Efficiency of Plant Extract to Neutralize Soil Acidity

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ABSTRACT

Water-soluble plant organic compounds have been proposed to be efficient in alleviating soil acidity. Laboratory methods were evaluated to estimate the efficiency of plant extracts to neutralize soil acidity. Plant samples were dried at 65°C for 48 h and ground to pass 1 mm sieve. Plant extraction procedure was: transfer 3.0 g of plant sample to a becker, add 150 ml of deionized water, shake for 8 h at 175 rpm and filter. Three laboratory methods were evaluated: $S(Ca+Mg+K)$ of the plant extracts; electrical conductivity of the plant extracts and titration of plant extracts with NaOH solution between pH 3 to 7. These methods were compared with the effect of the plant extracts on acid soil chemistry. All laboratory methods were related with soil reaction. Increasing $S(Ca+Mg+K)$, electrical conductivity and the volume of NaOH solution spent to neutralize H^+ ion of the plant extracts were correlated with the effect of plant extract on increasing soil pH and exchangeable Ca and decreasing exchangeable Al. It is proposed the electrical conductivity method for estimating the efficiency of plant extract to neutralize soil acidity because it is easily adapted for routine analysis and uses simple instrumentations and materials.

Key words: Plant residue, organic acid, plant alkaline index

INTRODUCTION

Plant residues release a range of low molecular weight organic acids such as maleic, citric, oxalic, salicylic, etc, which are involved in many soil processes including lime mobility (Ziglio et al., 1999; Miyazawa et al., 1998), metal organic complexing reactions (Franchini et al., 1999 and 2001), ion sorption (Bolan et al., 1994) and rhizosphere chemistry (Jones, 1998). These organic acids contain carboxyl and phenolic groups, thereby allowing the cation complexation reaction and the anion competition for a soil adsorption sites.

The ability of organic acids for cation complexation in solution is well established (Hue et al., 1986; Miyazawa et al., 1992) and has being attributed to the presence of the negative charges in the functional groups. Complexing formation depends on the number and the position of carboxyl and phenolic functional groups in the organic acids.

The composition of organic acids in plants is well documented (Curl & Trueglove, 1986; Aoyama, 1996). Using high performance size exclusion chromatography (Aoyama, 1996) and semi-quantitative techniques (Curl & Trueglove, 1986), they observed that the composition of organic acids in plants are highly variable and depends on

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plant species, plant age and physiochemical environment. Despite of this early works, however, the effects of plant organic acids on soil chemistry have only recently started to be elucidated (Miyazawa et al., 1998; Ziglio et al., 1999; Franchini et al., 1999; Meda et al., 1999). In general, these authors concluded that several plant residues are highly efficient in alleviating soil acidity.

The objectives of this work were to develop a laboratory method to evaluate the efficiency of water extracts of plant residues to neutralize soil acidity and to evaluate the most appropriate method for laboratory routine.

MATERIALS AND METHODS

Plant materials: black oats (*Avena strigosa*), oil seed radish (*Raphanus sativus*), white lupin (*Lupinus albus*), gray mucuna (*Stizolobium cinereum*), wheat straw (*Triticum aestivum*). The aereal parts of the black oats, oil seed radish, white lupin and gray mucuna were collected at flowering stage and wheat straw after grain's harvest.

Water plant extract: 3 g of dried plant material (aereal parts) were transferred to a plastic flask, added 150 ml of deionized water, shaked for 8 h at 175 rpm and filtrated. Sub samples of plant extracts were used for chemical analysis (Table 1). Basic cations (Ca, Mg, and K) were determined by ICP (Inductively Coupled Plasma).

Experiment with soil: acid soil sample taken from the 0-20 cm horizon was air-dried and passed through a 2 mm sieve. The soil had an original pH $CaCl_2$ value of 4.10; exchangeable Ca, Mg, K, and Al contents of 0.37, 0.17, 0.05, and 1.11 $cmol_c$ dm^{-3}, respectively, total acidity (H + Al) of 6.20 $cmol_c$ dm^{-3}, and total carbon content of 7.64 g kg^{-1}. The clay content was 27%, silt 2% and sand 71%. Soil sample was transferred to PVC column (30 cm high by 4 cm diameter) and compacted to a homogeneous bulk density (mean 1g cm^{-3}). Plant extract solution (150 ml) in amount equivalent to one porous volume (pV) was added on the soil surface. Then, deionized water was added in amount equivalent to three pV, to a total of 450 ml. Plant extract and water were added at a rate of 1.0 ml min^{-1}. Soil samples were collected at 0-5, 5-10, 10-15, 15-20 and 20-25 cm depth, air-dried, ground to pass 2 mm sieve and analyzed for pH

$CaCl_2$ and exchangeable Al_{ex} and Ca_{ex}. Extraction and determination methods were described by Pavan et al. (1992). All treatments had three replicates in a completely randomized block design.

Laboratory methods:

1. Summation of basic cations [S (Ca + Mg + K)]: sum of Ca, Mg, and K contents in the plant extract solution (Table 1).

2. Electrical conductivity (EC): measured with electrode installed into a becker containing a 10% diluted plant extract in deionized water at 25°C.

3. Capacity to reduce H^+ ion: transfer 25 ml of plant extract to a becker, set up a H^+ ion selective electrode into the becker, adjust to pH 3.0 with 2 mol L^{-1} HCl solution, titrate with 0.05 mol L^{-1} NaOH solution to pH 7.0, and register the volume of 0.05 mol L^{-1} NaOH spent. The pHs 3.0 and 7.0 were selected due to the maximum protonation and deprotonation, respectively, of the organic anions (Young et al., 1981).

RESULTS AND DISCUSSION

The pH, Ca_{ex}, and Al_{ex} by depth for the control and plant extract treatments are shown in figures 1, 2, and 3, respectively. Control soil had lower pH and Ca_{ex} and higher Al_{ex} contents. Additions of plant extracts increased soil pH and Ca_{ex} and decreased Al_{ex}, corroborating data presented in early studies with brazilian acid soils (Miyazawa et al., 1993 and 1998; Franchini et al., 1999 and 2000; Meda et al., 1999). These results show that the effect of plant extracts on soil acidity was highly variable and depended on plant species. In general, the effect of plant extract on soil acidity followed the order: oil seed radish > black oats > lupin > mucuna > wheat straw. Oil seed radish, black oats and lupin increased pH up to 20 cm soil depth. Oil seed radish and black oats neutralized totally Al_{ex} up to 10 cm soil depth and partially up to 25 cm soil depth. Except for wheat straw, the other plant extracts increased Ca_{ex} in the soil profile. Black oats and oil seed radish showed the greatest increment on Ca_{ex} in the soil profile. Oil seed radish was the most efficient to increase the total Ca_{ex} in the soil column. These results indeed

support the view the soluble organic compounds as short chain fatty acids in soil are mobile and efficient in alleviating soil acidity (Franchini et al., 2001).
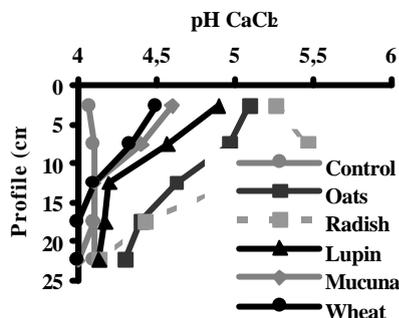
pH CaCl₂
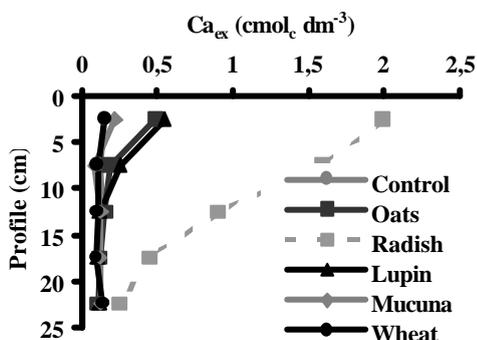

Figure 1 - Effect of plant extracts on soil pH.

Ca_ex (cmol_c dm⁻³)

Figure 2 - Effect of plant extracts on soil Ca_{ex}.

Al_ex (cmol_c dm⁻³)

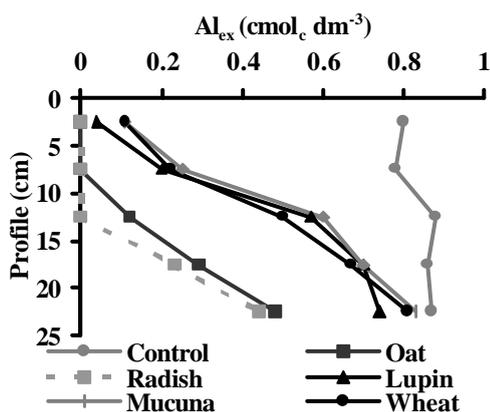**Figure 3** - Effect of plant extracts on soil Alex.

Table 1 shows the $\Sigma(Ca+Mg+K)$, the volume of NaOH spent during titration and the electrical conductivity of the plant extracts. The total

amount of basic cations, the volume of NaOH spent, and the values of electrical conductivity followed the order: oil seed radish > black oats > mucuna > lupin > wheat straw. This is the same order found for alleviating soil acidity (Figures 1, 2, and 3). Table 2 shows the regression equations and the correlation coefficients for soil pH, Al_{ex} and Ca_{ex} vs the three laboratory methods tested. These methods were highly correlated with soil parameters indicating that they can be used to estimate the efficiency of plant extract to neutralize soil acidity

Table 1 - Chemical composition of the plant extracts, volume of NaOH spent between pH 3 to 7, and the EC of the plant extract

Plant extract[1]	Composition (Σcations) mmol_c L⁻¹	NaOH volume[2] ml	EC mS
Black oats	27.6	11.6	5,870
Oil seed radish	40.3	14.4	6,680
Mucuna	10.4	6.4	2,360
Lupin	13.9	10.0	3,200
Wheat straw	2.1	6.0	2,120

[1.] 150ml columm⁻¹   [2.] 0.05 mol L⁻¹.

Table 2 - Regression equations and correlation coefficient for pH, Al and Ca vs Σcations, EC and the volume of NaOH spent during titration coefficients for soil pH, Ca_{ex} and Al_{ex} vs the three laboratory methods tested.

Regression equations/correlation coefficient (r)
pH (CaCl₂)= 4.11 + 0.02Σ(Ca+Mg+K) (mmol_c L⁻¹) r=0.98
pH (CaCl₂)= 3.91 + 0.0001EC (mS) r=0,99
pH (CaCl₂)= 3.70 + 0.08NaOHspent (ml) r=0.96
Al (cmol_c dm⁻³)= 0.55–0.01Σ(Ca+Mg+K)(mmol_c L⁻¹) r=0.93
Al (cmol_c dm⁻³)= 0.68 – 8x10⁻⁵EC (mS) r=0.98
Al (cmol_c dm⁻³)= 0.55 – 0.01NaOHspent (ml) r=0.93
Ca(cmol_c dm⁻³)=-0.06+0.02Σ(Ca+Mg+K)(mmol_c L⁻¹) r=0.84
Ca (cmol_c dm⁻³)= -0.21 + 0.0001EC(mS) r=0.75
Ca (cmol_c dm⁻³)= -0.53 + 0.09NaOHspent (ml) r=0.81

The greater amount of NaOH used, the higher content of basic cations and the higher electrical conductivity of the oil seed radish and black oats than wheat straw extract indicated a higher alkaline capacity of the oil seed radish and black oats. Due to its simplicity (instrumentation and materials) and for being easily adapted for routine analysis it is recommended the electrical conductivity method for estimating the efficiency of the plant extract to neutralize soil acidity.

CONCLUSION

The efficiency of plant extract to neutralize soil acidity can be estimated in the laboratory by sum of Ca, Mg, and K, the volume of NaOH solution spent between pH 3 to 7, and the electrical conductivity of the plant extracts. Due to its simplicity it is recommended the electrical conductivity method.

RESUMO

Tem sido proposto que os compostos orgânicos de plantas solúveis em água são eficientes na amenização da acidez do solo. Foram avaliados métodos de laboratório para estimar a eficiência dos extratos de plantas na neutralização da acidez do solo. Os materiais de plantas foram secos a 65° C por 48 horas, moídos e passados em peneira de 1mm. Utilizou-se o seguinte procedimento para obtenção do extrato de plantas: transferir 3.0 g da amostra de planta para um becker, adicionar 150 ml de água deionizada, agitar por 8h a 175 rpm e filtrar. Avaliaram-se três métodos de laboratório: Σ(Ca + Mg + K) do extrato de planta, condutividade elétrica (CE) do extrato de planta e titulação do extrato de planta com solução de NaOH entre pH 3 a 7. Os métodos de laboratório foram comparados com o efeito dos extratos de plantas na reação do solo. Todos os métodos de laboratório foram correlacionados com a reação do solo: o aumento de Σ(Ca + Mg + K), Ce e o volume de NaOH gasto para neutralizar os íons H$^+$ do extrato de plantas, foram correlacionados com o efeito nos aumentos de pH e Ca trocável e diminuição de Al trocável do solo. É proposto o método de CE para estimar a eficiência do extrato de plantas na neutralização da acidez do solo por ser facilmente adaptado para análise de rotina e por utilizar instrumentos e materiais simples.

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