MAGNESIUM SULPHATE AND THE DEVELOPMENT OF THE COMMON BEAN CULTIVATED IN AN ULTISOL OF NORTHEAST AUSTRALIA

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ABSTRACT: Magnesium applications ($MgSO_4.7H_2O$) to achieve 8 and 16 $mmol_c/cm^3$ of Mg (324 and 1284 kg of $MgSO_4$ ha^{-1}) were made on one Ultisol from Australia Northeast to correct Mg deficiency in plants and to verify the optimum level of Mg to grow common bean (*Phaseolus vulgaris* L). Magnesium was applied together with lime, N, K, Cu, Zn, B, and Mo as calcium carbonate, ammonium nitrate, potassium phosphate, cupric and zinc sulphate, boric acid and sodium molybdate respectively a month before planting and P as phosphoric acid at the planting. The pH reached the equilibrium after six weeks of incubation. Higher electrical conductivity (EC) was observed in soil where Mg was applied to reach 8 $mmol_c/cm^3$ in the absence of common bean and 16 $mmol_c/cm^3$ when the plant was present. Higher plant height, leaf area, dry matter weight:leaf area ratio and nutrient concentrations were observed in plants cultivated in soils treated with Mg to reach 8 $mmol_c/cm^3$ and 16 $mmol_c/cm^3$ when the plant was present. The plant top P content was very low but N, Ca and Mg contents can be considered normal for the common bean.
Key words: magnesium, plant height, soil pH, electrical conductivity

SULFATO DE MAGNÉSIO E O DESENVOLVIMENTO DO FEIJOEIRO COMUM CULTIVADO EM UM ULTISSOLO DO NORDESTE DA AUSTRALIA

RESUMO: Aplicações de sulfato de magnésio ($MgSO_4.7H_2O$) para atigir 8 e 16 $mmol_c/cm^3$ de Mg (324 e 1284 kg de $MgSO_4$ ha^{-1}) foram realizadas em um solo Ultissolo com a finalidade de corrigir deficiências de Mg no feijoeiro e verificar o nível de Mg suficiente para cultivar o feijão comum (*Phaseolus vugaris* L). O magnésio foi aplicado junto com calcário, N, K, Cu, Zn, B e Mo, como carbonato de cálcio, nitrato de amônio, fosfato de potássio, sulfato de cobre, sulfato de zinco, ácido bórico e molibidato de sódio respectivamente, um mês antes do plantio e o P como ácido fosfórico no plantio. O pH alcançou o equilíbrio após seis semanas de incubação. A condutividade elétrica mais alta (CE) foi observada em solo onde o Mg foi aplicado para atingir 8 $mmol_c/cm^3$ na ausência e 16 $mmol_c/cm^3$ na presença do feijoeiro A altura das plantas , área foliar, relação matéria seca/área foliar e concentrações de nutrientes no tecido foram maiores nas plantas cultivadas em solos tratados com Mg para atigir 8 $mmol_c/cm^3$. O teor de P foi muito baixo mas os de N, Ca e Mg podem ser considerados normais para o feijoeiro comum.
Palavras-chave: magnésio, altura da planta, pH do solo, condutividade elétrica

INTRODUCTION

Deficiencies of magnesium have been observed in points located in the great areas of natural pastures or in soils intensively cultivated, in areas where the acidity was not corrected appropriately and in places where horticulture is practiced under heavy fertilization and constant irrigation (Stephens & Donald, 1958, Embleton, 1973).

The magnesium can have its availability decreased by downward movement into the subsoil, together with other exchangeable cations to the deeper layers or being removed from the environment due to forage consumption in the cattle razing activities contributing indirectly with the acidification of the soil surface layer. In acid conditions, a progressive reduction of the phosphorus levels happens and available nitrogen and increases of the levels of aluminum, manganese and iron (Edwards & Bell, 1989; Stephens & Donald, 1958).

Being a demanding crop, the common bean (*Phaseolus vulgaris* L.) presents better production in weakly acid soils, with medium levels of calcium and magnesium, depending mainly on the clay contents (Oliveira et al., 1988). To correct faulty soils in magnesium it is recommended to apply dolomite lime or salts of magnesium directly to the soil, to reach concentrations between 5 to 10 $mmol_c/dm^3$, or in foliar solution, at the concentration of 1% (Kamprath & Foy, 1985; Mortvedt & Cox, 1985 and Rosolem, 1987).

This research was accomplished with the purpose of evaluating the effect of the application of increasing rates of magnesium on the development of the bean crop, in pH, electrical conductivity (EC), plant height, dry matter yield, leaf area and on the absorption of nitrogen, phosphorus, calcium and magnesium by the bean plant in soils corrected previously with calcitic limestone.

MATERIAL AND METHODS

Soil samples analyzed chemically showed for this Ultisol pH (1:5 soil:water) 4.24; electrical conductivity (EC) (1:5 soil:water); 0.028 $dS.cm^{-1}$, 4 $mmol_c/dm^3$ of Ca^{2+}, 5.3 $mmol_c/dm^3$ of Mg^{2+}, 1.1 mmol mc/dm^3 of Na^+, 1.3 $mmol_c/dm^3$ of K^+, cationic exchange capacity (CEC at the pH 7.0) 7.79 $mmol_c/dm^3$ and 85% of saturation of Al.

Flasks containing 400 g of soil wetted up to 2/3 of saturation were incubated for seven days to know the amount of water to be applied daily to maintain the soil at the moisture level between the field capacity and wilting point.

The soils were placed in two liter pots together with calcium carbonate (12t/ha) and fertilizers and were left for incubation until pH stabilization. Soil pH was determined in water (1:5 soil:water) and in $CaCl_2$ 0.05 M (1:5 soil:solution) in the absence of plants for a period of ten weeks.

The seeds were desinfected with silver nitrate in aqueous solution ($AgN0_3$) 0.01% during fifteen minutes.

Half of the nitrogen (60 kg of urea ha^{-1}), the potassium (100 kg of K_20 ha^{-1}), copper (4 kg of Cu ha^{-1}), zinc (4 kg of Zn ha^{-1}), boron (0.3 kg of B ha^{-1}), molybdenum (0.1 kg of Mo ha^{-1}), acid phosphate potassium (KH_2PO_4), copper sulphate ($CuS0_4$ $5H_20$), zinc sulphate ($ZnS0_4$ H_20), boric acid (H_3BO_3), sodium molybdate (Na_2Mo_4 $2H_20$), were applied a month before planting and the phosphorus (100 kg P ha^{-1}) as phosphoric acid (H_3PO_4) at plantig. The other half of the nitrogen was applied two times, at the 15 (30 kg of N ha^{-1}) and 35 (30 kg of N ha^{-1}) days after plant emergency as ammonium nitrate (NH_4NO_3).

Three levels of magnesium were studied: a) check - natural level of magnesium of the soil; b) application of magnesium, as sulphate of magnesium (324 kg of $MgSO_4$ ha^{-1}) enough to reach 8 $mmol_c/dm^3$ of Mg^{2+} and c) - 1.6 $mmol_c/dm^3$ of Mg^{2+} (1284 kg of $MgSO_4$ ha^{-1}).

Observations were made at 15 and 30 days after plant emergency.

Forty days after the emergency, the plants were sampled, weighted, measured for leaf area, height and dried in 60°C oven during 72 hours. Foliar samples were digested in nitric - perchloric solution for phosphorus, calcium and magnesium determination, and in sulfuric solution for nitrogen determination. The electrical conductivity of the soil was measured in the absence and in the presence of the plant at forty days.

The treatments were disposed in randomized blocks with four replicates.

RESULTS AND DISCUSSION

pH variations in water and in $CaCl_2$ 0.05 M were observed in soil treated with different levels of magnesium sulphate (Figure 1). The largest pH variations happened during the first six weeks of incubation and it was stabilized after the eighth week, indicating the necessary time for the whole corrective to react with the soil. The highest variations of pH were registered in the treatments check (0 = magnesium of the soil). The pH increases are attributed to the solvent effect of the magnesium sulphate, as of any other salt of sulfur, which solubilizes carbonates and other salts of the soil, reducing the environmental acidity due to the temporary elevation in the concentration of bases of the soil solution.

The electrical conductivity (EC) was monitored with the objective of verifying the saline effect of the fertilizers applied in the presence and in the absence of plants. Variations of the values of EC of the soil were verified with the application of fertilizers (Figure 2) but considered normal for non saline soils (Russel, 1949; Embleton, 1973; Maclahan, 1975 and Wild, 1988). The EC in the plant absence was larger when sulphate of magnesium was applied to reach 8 $mmol_c/dm^3$, but in the presence of the plant, the largest electrical conductivity was observed in the treatments that received sulphate to reach 16 $mmol_c/dm^3$ of Mg. Certain amounts of sulphates applied to the soil produce acids wich solubilize some salts and increase, for some time, the concentrations of calcium, potassium, sodium and other cations in the soil solution, increasing the EC. Similar observations were made by Wilcox (1947) in relation to irrigated tropical soils of the semi-arid areas, when cultivated intensely, or when over fertilizing and amendment led to salinization due to the high contents of soluble salts, turning them inappropriate for the development of the plants.

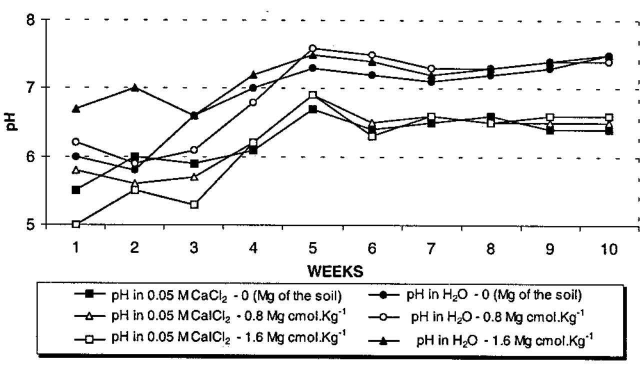

Figure 1 - pH in soil incubated with calcium carbonate.

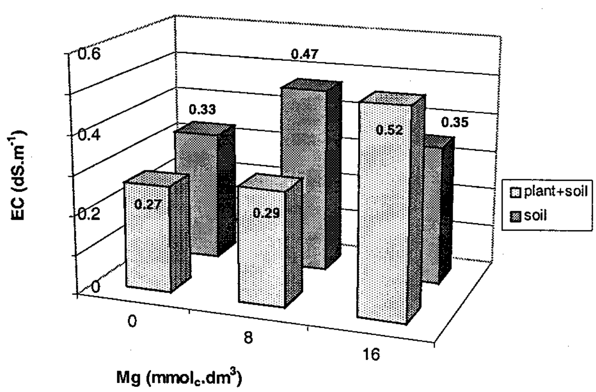

Figure 2 - Electrical conductivity (EC) of the soil submitted to increasing levels of magnesium sulphate.

When the plant was present, the e EC increased with the application of higher doses of magnesium sulphate. The results can be explained by the beginning of the relative absorption, when the plant absorbs cations, new cations are liberated, contributing, in that way, to increase the EC in the presence of the highest levels of magnesium sulphate.

Plant height (Figure 3), total weight of the dry matter, foliar area and weight of the dry matter : foliar area ratio (Figure 4) were larger when magnesium sulphate was applied to reach 8 $mmol_c/dm^3$ of Mg^{2+}. More expressive differences were observed among determinations taken in 30 days old than 15 days old plants. During the initial process of development of the bean plant, the increases in the height are processed quickly, after that the growth of trifoliate leaves continues intense until the end of the flowering phase (Noggle & Fritz, 1983). Polygonal diagrams developed by those authors have been used to show the importance of complete solutions of nutrients for the development of the plants. The magnesium has been shown as an important nutrient in the production of green mass. If the plants were developed until grain formation, the dry weight could continue to increase for an additional period during the bean formation, covering the seed development and maturation.

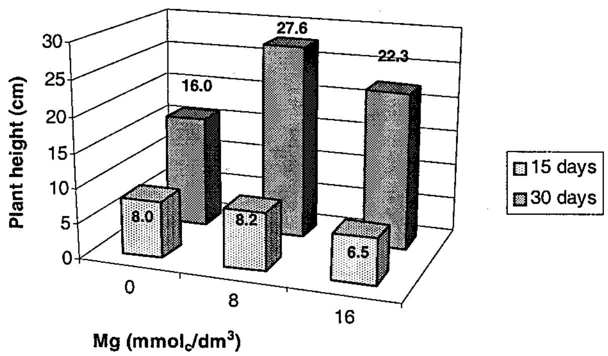

Figure 3 - Height of the plants grown under increasing levels of magnesium sulphate.

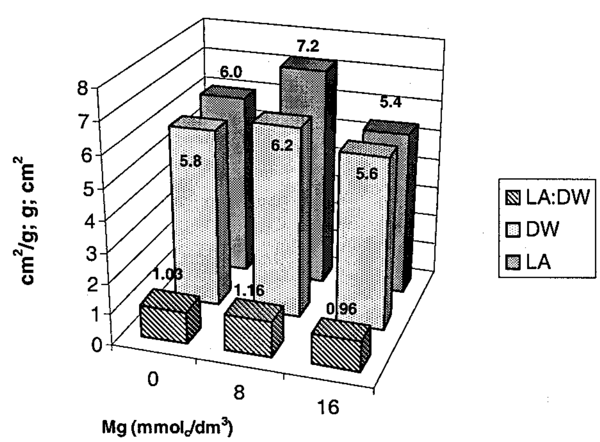

Figure 4 - Leaf area (LA), dry weigh of the shoot (DWS) and dry matter weight : leaf area (DW: LA) of bean plant submitted to increasing magnesium sulphate.

The leaf area (LA) (Figure 4) presented the same tendency of the production of dry matter. The development of the LA was associated with the level of the magnesium applied (Hewitt & Smith, 1874; Jones, 1973), that presents a direct relationship with the concentration of magnesium in the plant tissue and the amount of synthesized chlorophyll. The development of the leaf is influenced, among several environmental factors, by the nutritional condition under which the plant is submitted (Hughes & Henson, 1975; Mengel & Kirkby, 1978) at the same time, indexes of foliar area were related with the level of carbon dioxide of net carbon and with the rate of net photosynthesis directly related with the chlorophyll content. These results can be attributed to the magnesium used as fertilization which has influenced the plant growth by increasing the foliar area and dry mass production and also by the dry weight : foliar area ratio (Figure 4).

Zimmerman (1947) reported that the magnesium is very important for the plant nutrition at high fertility levels, not only to balance the effect of the calcium but to balance the high potassium levels and vice versa. At low fertility levels, the absorption of magnesium is closely related with the potassium supply. Harmful effects of the magnesium in excess have been reported by Tayel et al., 1980a, 1980b; Levy et al., 1988 in the deterioration of the soil physical properties, reducing the concentrations of air and of water, influencing the lengthening of the root negatively.

The application of the magnesium to reach 8 $mmol_c/dm^3$ had small influence in the content of the nitrogen, phosphorus and calcium of the plant shoots (Figs. 5 and 6), while the largest rate of magnesium applied in the soil reduced the absorption of those nutritients. At the same time, the largest absorption of magnesium was observed when increasing rates of magnesium sulphate were applied.

Several authors (Walker et al., 1989; Huang et al., 1990) have shown a direct correlation among leaf concentrations of magnesium, nitrogen, calcium and phosphorus with the root development and formation of rizobia and in the intensity of nodulation in leguminous crops.

The production of total dry matter (Figure 4) was also larger in soils which received magnesium to reach 8 $mmol_c/dm^3$. Polygonal diagrams of Noggle & Fritz (1983) have been used to show the importance of complete nutrient solutions for the plant development. The magnesium showed considerable importance in green mass production and in plant height, except for that period of fast plant growth with high dry matter production and increasing dry weight: leaf area ratio (Figs.6 and 7).

The soil pH was approximately the same since the planting until the harvesting time (Figs. 1 and 7). The pH read in the water suffered larger variation than that pH read in $CaCl_2$ 0.05 M solution. The higher EC has indicated that the soil possesses larger concentrations of salts after fertilization and the pH reduction is a result of the compression of the double electric layer caused by the addition of electrolyte or salts as $CaCl_2$ 0.05 M . This compression forces the hydrogen to move from the double layer to the soil solution. The concentration of $CaCl_2$ 0.05 M is enough to level the effect of the salts usually present in non saline soils, eliminating the variation in the gradient of hydrogen of the diffuse layer. As a result, constant readings are obtained without interference of the external atmosphere in those soils exhaustively drained by the crop.

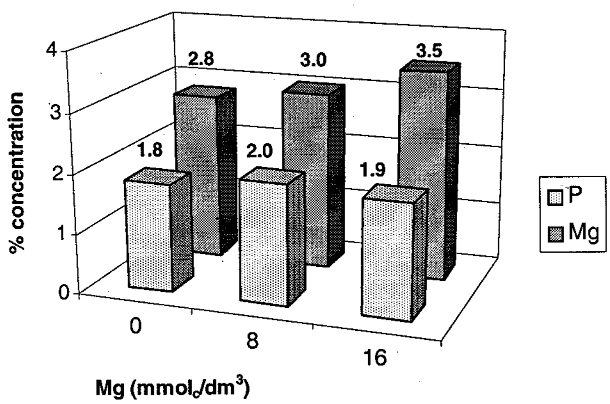

Figure 5 - Absorption of magnesium and phosphorus under increasing levels of magnesium sulphate.

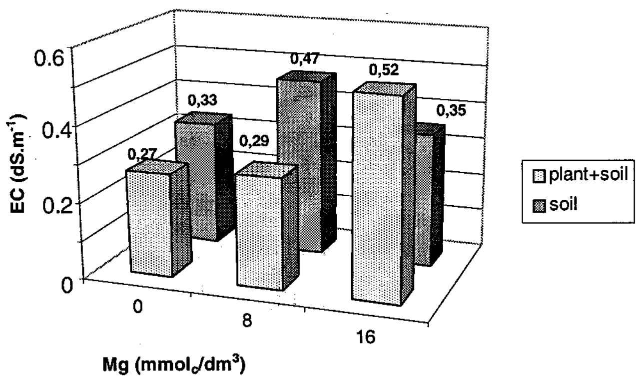

Figure 6 - Absorption of calcium and nitrogen under increasing levels of magnesium sulphate.

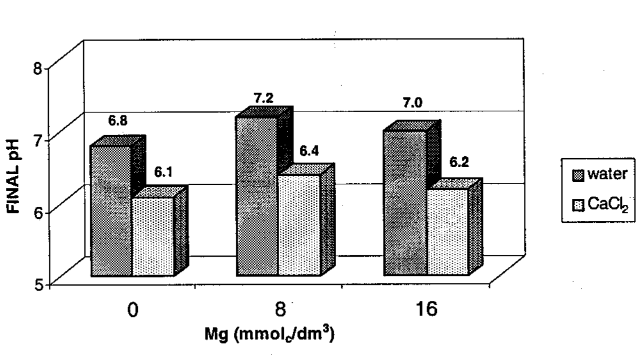

Figure 7 - Effect of increasing doses of magnesium sulphate in the pH at that time of crop of the common bean.

CONCLUSIONS

• A higher electrical conductivity (EC) was observed when sulphate of magnesium was applied to reach 8 $mmol_c/cm^3$ of Mg in the soil in the absence of the plant. When the plant was present, there was an increase of EC, proportional to the amount of magnesium sulphate applied.

• Plant height, green and dry matter yield and leaf area: dry matter weight ratio presented better results in the soil containing 8 $mmol_c/cm^3$ of Mg.

• The absorption of magnesium was proportional to the rates of magnesium sulphate applied. However, the absorption of most of the nutrients was larger when the bean was developed in the presence of 8 $mmol_c/cm^3$ of Mg.

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