

## Effect of potassium on moringa plants growth in nutriente solution

Lucia Helena Garófalo Chaves<sup>1</sup>; Ricardo Almeida Viégas<sup>2</sup>; Ana Carolina Feitosa de Vasconcelos<sup>3</sup>, Hugo Vieira<sup>4</sup>

### ABSTRACT

The work was carried out to evaluate the effects of  $K^+$  rates on the initial growth as well as on the partition and accumulation of this element in roots, stems and leaves of moringa (*Moringa oleifera* Lam.) plants. A pot ( $0.5 \text{ dm}^3$ ) experiment was carried out under greenhouse conditions using river sand as substrate irrigated with nutrient solution twice every day. The experiment that was a completely randomized design had six treatments and three replicates. The treatments consisted of nutrient solution free of  $K^+$  (control) or supplied with 2, 4, 6, 8 and 12 mM of  $K^+$  as KCl salt. After germination and the period necessary for the plants to stabilize in conditions of the experiment they had been irrigated with  $K^+$ - nutrient solution treatments during 30 days. The experiment was harvested 80 days from transplanting.  $K^+$ ,  $Ca^{2+}$  and  $Mg^{2+}$  contents in roots, stems and leaves were determined. Through the growth analysis the leaf mass ratio, the efficiency of  $K^+$  translocation and use were calculated. The results have showed that *Moringa oleifera* was not responsive to the  $K^+$  external concentration above 2 mM. The  $K^+$  accumulation in stems was higher than in roots and leaves. The treatments had not influenced on the translocation efficiency of  $K^+$  throughout the plants. Finally, the plants showed to be more efficient to use  $K^+$  under conditions of a lower concentration of this ion in the nutrient solution.

**Keywords:** ion translocation, *Moringa oleifera*, potassium

### RESUMO

O trabalho foi realizado em casa de vegetação objetivando avaliar os efeitos de diferentes doses de  $K^+$  no crescimento inicial das plantas de moringa (*Moringa oleifera* Lam.) e no acúmulo deste elemento nas raízes, caule e folhas das plantas. Os tratamentos consistiram em cinco doses de potássio, 2, 4, 6, 8 e 12 mM e um sem potássio (controle) sendo o KCl a fonte do referido elemento. O delineamento experimental utilizado foi o inteiramente casualizado, com três repetições. Cada unidade experimental correspondeu a um vaso com  $0,5 \text{ dm}^3$  de areia de rio, como substrato, com uma planta, que era irrigada com solução nutritiva duas vezes ao dia. Após a germinação e o período necessário para as plantas estabilizarem-se nas condições do experimento, elas foram irrigadas durante 30 dias com a solução nutritiva e os tratamentos com  $K^+$ . As plantas foram colhidas 80 dias após o transplante e foram submetidas à análises, tendo sido determinado os teores de  $K^+$ ,  $Ca^{2+}$  e de  $Mg^{2+}$  nas raízes, caules e folhas. Através dos parâmetros de crescimento, foram calculadas a razão de massa foliar, a eficiência de translocação e a eficiência de utilização de  $K^+$ . Os resultados mostraram que a *Moringa oleifera* não é responsiva à concentração externa de  $K^+$  acima de 2 mM. O acúmulo de  $K^+$  nos caules foi mais elevado do que nas

raízes e folhas. Os tratamentos não influenciaram na eficiência de translocação de  $K^+$  nas plantas. Finalmente, as plantas mostraram ser mais eficientes em usar  $K^+$  sob as circunstâncias de baixa concentração deste íon na solução nutritiva.

**Palavras-chave:** translocação de íon, *Moringa oleifera*, potássio

## 1 - INTRODUCTION

*Moringa oleifera* Lam., belonging to the Moringaceae family, consists of only one genus (*Moringa*) and fourteen recognized species. It is a native plant from north of India and it has been cultivated in several tropical countries. *Moringa* is a multiple-use plant but it has been more intensely used in the industry, medicine and in the feeding human and animal as protein source. It was introduced in Brazil in 1985 and its excellent adaptation to soils and climate of Brazilian northeast Semi-Arid region (Bakke, 2001) has motivated the researchers to study its behavior when it is cultivated in salinity conditions. Salinity severely limits plant growth (Silveira et al., 2003) and it is an environmental stress strongly correlated with the use of irrigation mainly in Semi-Arid regions around world (Viégas et al., 2004).

Potassium (K) is an important macronutrient and the most abundant cation in higher plants. K has been the target of some researchers mainly because it is essential for enzyme activation, protein synthesis and photosynthesis ((Marschner, 1995; Silva, 2004), and it mediates osmoregulation during cell expansion, stomatal movements and tropisms. Furthermore, K is necessary for phloem solute transport and for the maintenance of cation:anion balance in the cytosol as well as in the vacuole. K supply from soil can be rate limiting for agricultural production.

Under conditions of osmotic and ionic stress, to know the K dynamic of plant is very important (Flowers, 2003) because the  $K^+$  ion, such as prolina, and some others N compounds (Munns, 2002), plays a pivotal role in the cell osmotic adjustment and ion homoeostasis (Silveira et al., 2003). Moreover the plants present distinguishable responses to that nutrient. In spite of this, not many scientific works has reported results about moringa mineral nutrition especially with regard to  $K^+$ .

The scientific literature has shown that many forest species do not respond to the application of  $K^+$  suggesting they are adapted to reduced availability of this nutrient, possibly due to an efficient uptake and/or use (Silva et al., 1996). In this context, some research has been developed to evaluate the characteristics and mechanisms that determine differences in the ability of  $K^+$  uptake and use (Furlani et al., 1986; Silva, et al., 1996; Vilela & Bull, 1999). Thus, the current study focus on the effect of the increase in external  $K^+$  concentration on the initial growth as well as on the partition and accumulation of this ion nutrient between roots, stem and leaves of moringa plants.

## 2 - MATERIALS AND METHODS

An experiment was carried out at the Agricultural Engineering Department of The Federal University of Campina Grande, Campina Grande, Brazil, under greenhouse conditions, from

March to May 2002, in a completely randomized design, with three replicates and six treatments. The treatments consisted of one control (none K) and five levels of K<sup>+</sup> (2, 4, 6, 8 and 12 mmol. L<sup>-1</sup>) added to the nutrient solution as KCl. Analyses of variance were performed on all data. Means were compared using the Tukey test at a 0.05 significance level.

*Moringa oleifera* seeds were surface-sterilized in 0.5% v/v sodium hypochlorite for 10 min (Silveira et al., 2001), followed by rinsing in pure water to allow a complete removal of the used sodium hypochlorite solution. To the end of this phase, the seeds had been completely immersed in distilled water, for a period 24-hour, with the objectives to speed up the germination process. After this period seeds were placed to germinate in plastic pots containing washed river sand as substratum moistened daily with 1.0 mM CaSO<sub>4</sub>. Previously this substratum had been washed with hydrogen chloride (HCl) solution prepared with 1 part of acid: 10 parts of pure water to remove the colloidal fractions as well as the present ions, followed by rinsing in pure water.

After fifteen days seedlings of uniform size, with 10 cm of height and two pairs of definitive leaves were selected and transplanted individually to plastic pots (0.5 dm<sup>3</sup>) containing washed river sand as substratum. In the first ten days seedlings were irrigated two times every day with Hoagland & Arnon (1950) nutrient solution with 10% of its original ionic force. The required concentration of this solution, 80% of original ionic force, was reached by increasing the solution ionic force for ten days to allow the seedlings to adapt gradually. Seedlings were allowed to establish in this conditions for fifteen days before the K treatments were imposed.

Plants were irrigated with K treatments solution during 30 days. Usually the volume solution used to irrigate the plants was more than 200 mL planta<sup>-1</sup> dia<sup>-1</sup> and it changed according with plant growth stages and climatic conditions. Such procedure has been needed to keep both ion concentration and pH around roots with no major variations throughout all experiment. The pH of nutrient solution utilized to irrigate the plants was adjusted to 5.5 ± 0.5 range using 0.1 M KOH or HCl.

The experiment was harvested 80 days from transplanting. At harvest, plants were divided into roots, stems and leaves; these plant parts were placed in paper bags, oven dried at 60°C for four days and the dry weights of these parts were determined. Dried roots, stems and leaves were finely ground in a stainless still mill and subsamples were subjected to nitric-perchloric digestion according to procedures described by Sarruge and Haag (1974). Samples of the resulting extract were taken to determine the ion content. K<sup>+</sup> was determined by flame photometer and Ca<sup>2+</sup> and Mg<sup>2+</sup> were determined by atomic absorption spectrophotometry (Malavolta et al., 1997).

Through the growth analysis the leaf mass ratio was esteemed (LMR) that express the relation between the dry mass leaf (g) (DML)/ total dry mass (g) (TDM). Also some indices of nutritional efficiency had been calculated: Efficiency of Translocation (TE) = content (mg) K<sup>+</sup> in the dry mass of the aerial part (ADM)/content (mg) of K<sup>+</sup> in the total dry mass (TDM); and the Efficiency of Use (UE) = total dry mass (g) (TDM)<sup>2</sup>/content (mg) of K<sup>+</sup> in the TDM.

Analyses of variance were performed on all data. Means were compared using the Tukey test at a 0.05 significance level.

### 3 - RESULTS AND DISCUSSION

Internal content of  $K^+$ ,  $Ca^{2+}$  and  $Mg^{2+}$  were measured in stems, leaves and roots of plants grown at different external  $K^+$  concentrations (Table 1). The plants  $Ca^{2+}$  concentration with respect to the increase in the external  $K^+$  concentrations was not significant ( $p > 0.01$ ). However there was a small decline in stems  $Ca^{2+}$  concentration as external  $K^+$  increased. On the other hand, increasing  $K^+$  concentration in the growth medium induced a significant decrease ( $p < 0.01$ ) in the accumulation of  $Mg^{2+}$  in the plants. It has been known for a long time that increasing external  $K^+$  concentration has a negative effect on the absorption process of  $Mg^{2+}$  and  $Ca^{2+}$  (Tisdale et al. 1975; Barros et al.1990) and the mechanisms involved are not known yet. However, it has been suggested that they are associated to alterations in the permeability of plasmalema (Salisbury and Ross, 1991). Therefore, it is probable that  $K^+$  places some  $Ca^{2+}$  adsorption positions in plasmalema as do  $Na^+$  inducing modifications in the ionic selectivity during the  $K^+$  uptake process (Maser et al., 2002; Viégas et al., 2004). The intensity and/or expression of this phenomenon depend on plant species.

**Table 1.** Potassium, calcium and magnesium concentrations in stem, leaf and root of moringa plants in function of potassium rates.

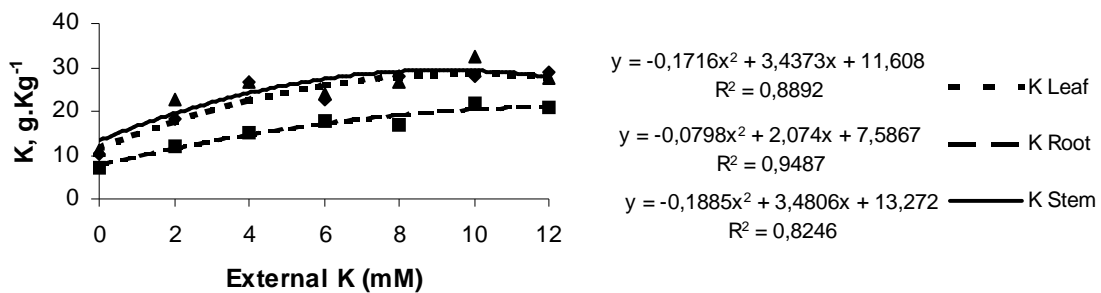
	Treatments (mmol K L <sup>-1</sup> )							CV
	0	2	4	6	8	10	12	
	-----g kg <sup>-1</sup> DM-----							%
<b>Stem</b>								
Potassium	11,12 c <sup>(1)</sup>	22,49 b	26,56 ab	24,12 b	26,56 ab	32,24 a	27,37 ab	10,24
Calcium	7,93 a	6,85 a	6,12 a	5,76 a	5,76 a	3,95 a	7,21 a	26,39
Magnesium	2,80 a	2,71 ab	2,90 a	2,29 bc	2,08 c	2,12 c	2,17 c	6,69
<b>Leaf</b>								
Potassium	10,31 c	18,43 b	26,56 a	22,49 ab	28,18 a	28,18 a	28,99 a	11,63
Calcium	23,51 a	23,51 a	22,43 a	22,06 a	22,43 a	20,98 a	23,88 a	12,50
Magnesium	7,25 a	6,35 ab	5,43 bc	5,15 bc	5,43 bc	4,73 c	4,64 c	10,11
<b>Root</b>								
Potassium	7,06 c	11,94 bc	15,19 abc	17,62 ab	16,81 ab	21,68 a	20,87 a	18,94
Calcium	10,11 a	12,28 a	13,37 a	9,02 a	10,83 a	9,75 a	10,47 a	24,28
Magnesium	2,94 ab	3,10 ab	3,36 a	2,60 bc	2,55 bc	2,18 c	2,18 c	9,18

(1) Means with the same letter in the lines indicate no difference among treatments at a 5% probability level

Results in Table 1 indicate that  $K^+$  accumulation in plants in 2 mM  $K^+$  treatment was 50% higher ( $p < 0,05$ ) than in control plants. However, in  $K^+$  external concentration above 2 mM the additions observed in the accumulation of this nutrient in the three organs studied had been proportionally lesser than the increases in its concentrations in the nutrient solution (Table 1). For example, as external  $K^+$  varied from 2 to 12 mM (an increase of 600% in the external  $K^+$  concentration) it concentrated in root, stem and leaf by 48, 18 and 37% more than in control, respectively.

It is important to observe that, although the internal  $Ca^{2+}$  concentration has been reduced in the stem with respect to  $K^+$  treatments (not significant differences) (Table 1), this part of the plant was the one that, in absolute terms, has presented greater profit of dry matter (DM) (Table 2). Probably, this reduction in the  $Ca^{2+}$  concentration is related with stem  $K^+$  accumulation.

Analyzing the results in terms of kinetic of  $K^+$  accumulation (Figure 1), it is observed that from 4 mM  $K^+$  there was a trend of  $K^+$  saturation in stem and leaves and, in the roots, this saturation was observed from 8 mM  $K^+$ . Considering these results and assuming that the total content of  $K^+$  ( $\Sigma$  of the  $K^+$  individual concentrations in the roots, stem and leaves) in the plant in 2 mM  $K^+$  treatment represented 66.48% of that one observed in 12 mM  $K^+$  treatment (Table 1 and 2), it can be suggested that the  $km$  for  $K^+$  during the absorption process is achieved in external  $K^+$  concentration bellow 2 mM. This assumption becomes more evident when  $K^+$  concentration in the leaves above 11,12g  $kg^{-1}$  DM (control) is not metabolically active in relation to DM production (Table 2). Thus, in spite of  $K^+$  to be taken up by the plants via two different uptake systems: system I, of low ( $\mu M$ ) and II, of high (mM) affinity, one can suggest that *Moringa oleifera* has employed system I rather than system II. This allows that a concentration corresponding to  $K^+$  tissue critical level is attained by moringa plants even under a reduced availability of this nutrient around roots. This suggestion is corroborated by the fact that the DM productions of stem, roots and leaves (Table 2) had been relatively insensitive ( $p > 0,05$ ) to the increases in the  $K^+$  concentration in the leaves above of 10,31 g  $kg^{-1}$  DM, that corresponds to 0,26 mol of  $K^+$   $kg^{-1}$  DM.



**Figure 1.**  $K^+$  accumulation in stem, leaf and root after exposure *Moringa oleifera* plants to increasing external  $K^+$  concentrations

**Table 2.** Production of dry matter of stem (DMS), leaf (DML) and root (DMR) of moringa plants, leaf mass ratio (LMR) and efficiency of translocation (TE) and of use (UE) of potassium, in function of potassium rates.

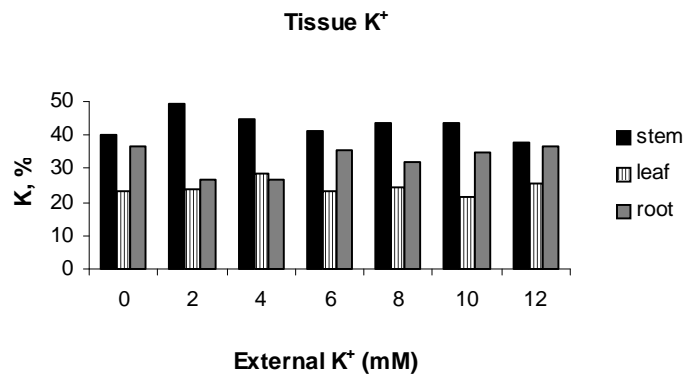
	Treatments (mmol $K L^{-1}$ )							CV(%)
	0	2	4	6	8	10	12	
DMS, g plant <sup>-1</sup>	15,09 a <sup>(1)</sup>	18,76 a	17,65 a	17,02 a	19,93 a	18,17 a	17,67 a	11,94
DML, g plant <sup>-1</sup>	9,45 a	11,10 a	11,27 a	10,34 a	10,31 a	10,44 a	11,33 a	13,49
DMR, g plant <sup>-1</sup>	21,81 a	18,88 a	18,65 a	20,04 a	22,70 a	22,67 a	22,49 a	7,06
LMR, g g <sup>-1</sup>	0,237 a	0,228 a	0,237 a	0,218 a	0,196 a	0,202 a	0,219 a	15,44
TE, mg mg <sup>-1</sup>	0,635 bc	0,734 a	0,730 ab	0,643 abc	0,682 abc	0,648 abc	0,631 c	5,23
UE, g <sup>2</sup> mg <sup>-1</sup>	5,21 a	2,81 b	2,16 b	2,26 b	2,34 b	1,96 b	2,06 b	18,38

(1) Means with the same letter in the lines indicate no difference among treatments at a 5% probability level

From the current data it can be speculated that the moringa plants present high selectivity for  $K^+$ . This fact is of great physiological significance for two inherent reasons: 1- it allows that even under a reduced availability of external  $K^+$  an accumulation of this nutrient in tissue

compatible to the growth requirement is observed; 2- in conditions of salt stress, for example, a high  $K^+/Na^+$  selectivity of the  $K^+$  uptake system constitutes in an excellent form to control excess  $Na^+$  absorption preventing its toxicity and also modifications in cell homeostasis.

The increase of the  $K^+$  concentration in the growth medium induced significant accumulation of this nutrient in the roots, stems and leaves, particularly when the results relative to 1 and 12 mM  $K^+$  treatments are compared (Figure 1); this accumulation, however, have not undergone modifications in the accumulation pattern of  $K^+$  in the different parts of the plant, compared to that one seen in the control plants. So, in absolute terms (total accumulated between root, stem and leaf) the concentration of this nutrient was higher in stems and leaves, followed for the roots ( $p < 0,05$ ) (Table 1). In relative terms that accumulation pattern is modified in all treatments (Figure 2). This demonstrates that the  $K^+$  absorption and distribution through the plants are processes not coordinated and therefore under different controls.



**Figure 2.**  $K^+$  partitioning among stem, leaf and root after exposure *Moringa oleifera* plants to increasing external  $K^+$  concentrations

The efficiency indices, in function of the treatments, are observed in Table 2. With respect to the efficiency of  $K^+$  translocation between root, stem and leaf of moringa plants some significant effect of the treatments was observed. This result is in line with that reported by Silva et al. (1996) on other forest species. It is likely that this has occurred due to the fact that the relative rates of  $K^+$  present in the shoot (leaves + stem) of the moringa plants did not increase as external  $K^+$  rises. This result further straightens the suggestion that  $K^+$  absorption and its distribution through different organs of moringa plants are distinct processes (see comments above). Also, it is observed that moringa plants reduced its efficiency to use  $K^+$  in function of the increases in concentration of this nutrient in the nutrient solution and that such reduction was significant in relation to control. This indicates that moringa plants have been more efficient to use  $K^+$  when the availability (quantitative) of this nutrient is lesser; this result agrees to that one reported by Silva et al. (1996).

According to Siddiqi and Glass (1981), such behavior occurs due the growth of the plants (in relation to dry mass produced) that received increasing amounts of  $K^+$  has not increased in the same ratio that the concentration of this element in analyzed tissue. This means that the plant when submitted to conditions of higher availability of  $K^+$  has its capacity to convert the absorbed nutrient into dry matter reduced. Still, LMR, as shows Table 2, did not significantly vary in relation to treatments; therefore, it is probable that the increases in  $K^+$  concentration in

the tissue has not influenced on the distribution of proteins and carbohydrates from one organ to another.

### 3- CONCLUSIONS

1. *Moringa oleifera* is not responsive to external  $K^+$  concentration above 2 mM.
2. The  $K^+$  accumulation was higher in stem than in roots and leaves.
3. The treatments had not influenced on the efficiency of  $K^+$  translocation through the plant.
4. The plants had been more efficient to use  $K^+$  under conditions where a less concentration of this nutrient is available.

### 4 - REFERENCES

BAKKE, I.A. *Características de crescimento e valor forrageiro da moringa (moringa oleifera lam.) submetida a diferentes adubos orgânicos e intervalos de corte*. Areia, 2001, 46p. (Dissertação de Mestrado) - Universidade Federal da Paraíba.

BARROS, N.F. & NOVAIS, R.F. *Relação solo-eucalipto*. 1th ed. Viçosa: Folha de Viçosa, 1990. 330p.

FURLANI, A.M.C.; BATAGLIA, O.C. & AZZINI, L.E. Variabilidade entre linhagens de arroz na absorção e utilização de potássio em solução nutritiva. *Revista Brasileira de Ciência do Solo*, v.10, p.51-59, 1986.

HOAGLAND, D.R. & ARNON, D.I. *The water culture method for growing plant without soil*. Berkley:California Agricultural Experiment Station, 1950. 39p. (Bulletin 347).

MALAVOLTA, E.; VITTI, G. & OLIVEIRA, S.A. *Avaliação do estado nutricional das plantas: Princípios e Aplicações*. 2ed. Piracicaba:Potafos, 1997, 319p.

MARSCHNER, H. *Mineral nutrition of higher plants*. London: Academic Press, 1995. 889p

MASER, P.; GIERTH, M. & SCHROEDER, J.I. Molecular mechanisms of potassium and sodium uptake in plants. *Plant and Soil*, v.247, p.43-54, 2002.

MUNNS, R. Comparative physiology of salt and water stress. *Plant Cell Environment*, v.25, p.659-151, 2002.

SALISBURY, F. P. & ROSS, C. *Plant Physiology*. 4th ed. Belmont: Wadsworth Publishing Company, 1991. 682 p.

SARRUGE, J.R. & Haag, H.P. *Análise química de plantas*. Piracicaba: ESALQ,1974. 56p.

SIDDIGI, M.Y. & GLASS, A.D.M. Utilization index: a modified approach to the estimation and comparison of nutrient utilization efficiency in plants. *Journal Plant Nutrition*, v.4, p.289-302, 1981.

SILVA, I.R.; FURTINI NETO, A.E.; VALE, F.R. & CURI, N. Eficiência nutricional para potássio em espécies florestais nativas. *Revista Brasileira Ciência do Solo*, v.20, p.257-264, 1996.

SILVA, S.L.F. *Transpiration and ion partitioning in grafted seedlings and rootstocks of different cashew genotypes exposed to salt stress*. Fortaleza, 2004, 65p. (Dissertação de Mestrado) - Universidade Federal do Ceara.

SILVEIRA, J.A.G.; MELO, A.R.B.; VIÉGAS, R.A. & OLIVEIRA, J.T.A. Salinity-induced effects on nitrogen assimilation related to growth in cowpea plants. *Environmental and Experimental Botany*, v.46, p.171-179, 2001.

SILVEIRA, J.A.G.; VIÉGAS, R.A.; ROCHA, I.M.A.; MOREIRA, A.C.O.M.; MOREIRA, R.A. & OLIVEIRA, J.T.A. Proline accumulation and glutamine synthetase activity are increased by salt-induced proteolysis in cashew leaves. *Journal of Plant Physiology*, v.160, p.115-123, 2003.

TISDALE, S.L.; NELSON, W.L. & BEATON, J.D. (1975) *Soil fertility and fertilizers*. 4ed. New York: Macmillan Publishing Company, 1975.754p.

VIÉGAS, R.A.; FAUSTO, M.J.; SILVEIRA, J.A.G. & QUEIROZ, J.E. Growth and total -N content of *Prosopis juliflora* (SW) D. C. are stimulated by mild NaCl level. *Brazilian Journal of Plant Physiology*, v.16, p.65-68, 2004.

VILELA, E.F. & BULL, L.T. Avaliação do crescimento de plantas de milho em função de doses de potássio e estresse hídrico. *Revista Brasileira de Ciência do Solo*, v.23, p.281-289, 1999.

---

[1] - Engenheira Agrônoma, Dr<sup>a</sup>, Prof<sup>a</sup>. Titular. Departamento de Engenharia Agrícola. UFCG. Av. Aprígio Veloso, 882. Campina Grande, PB. E-mail: lhgarofalo@hotmail.com

[2] - Engenheiro Agrônomo, Dr. Prof. Departamento de Engenharia Florestal. UFCG, CP 64, CEP 58700-970, Patos, PB

[3] - Engenheira Agrícola, Doutoranda em Solos e Nutrição de Plantas, ESALQ/USP. E-mail: [ana3carol@hotmail.com](mailto:ana3carol@hotmail.com)

[4] - Engenheiro Agrônomo, Mestrando em Engenharia Agrícola, CTRN/UFCG