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Macronutrients in watermelon plants fertilized with potassium and cattle manure

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Key words:

Citrullus lanatus
organic matter
mineral nutrition

ABSTRACT

Potassium is the nutrient required in greatest quantity by watermelon, especially during the production phase. Therefore, the aim of this experiment was to evaluate the effect of potassium and cattle manure doses on the nutritional composition of 'Crimson Sweet' watermelon plants. The treatments were arranged in a randomized block design with three replicates and 21 plants per plot using a $3 \times 5 + 1$ factorial scheme, referring to three manure doses (0; 1,100 and 2,520 g hole⁻¹), in order to increment the level of soil organic matter from 0.67 present in the soil to 3.0 and 6.0%, five potassium doses (0, 7.5, 15, 22.5 and 30 kg ha⁻¹) in the form of potassium chloride and one additional treatment (without organic and mineral fertilization). At the beginning of fruiting, leaves were collected to evaluate the nutritional status of the plants in macronutrients. According to the results, cattle manure stimulates the absorption of macronutrients by watermelon; in soil with 3.0% of organic matter, the best results corresponded to the K₂O dose of 15 kg ha⁻¹ and, for 6.0%, between 11 and 13 kg ha⁻¹.

Palavras-chave:

Citrullus lanatus
matéria orgânica
nutrição mineral

Macronutrientes em plantas de melancia adubadas com potássio e esterco bovino

RESUMO

O potássio é o nutriente mineral exigido em maior quantidade pela melancieira principalmente na fase de produção. Este trabalho objetivou avaliar o efeito de doses de potássio e esterco bovino na composição foliar de melancieira. Os tratamentos foram distribuídos em blocos ao acaso com três repetições e 21 plantas por parcela em arranjo fatorial $3 \times 5 + 1$, referentes às três doses de esterco bovino (0; 1.100 e 2.520 g cova⁻¹), para elevar o teor de matéria orgânica de 0,67% que o solo possuía, para 3 e 6%, cinco doses de K₂O (0; 7,5; 15; 22,5 e 30 kg ha⁻¹) utilizando-se KCl como fonte e um tratamento adicional (sem adubação orgânica e mineral). No início da frutificação foram colhidas folhas para avaliação do estado nutricional das plantas em macronutrientes (N, P, K, Ca, Mg e S). O esterco bovino estimula a absorção de macronutrientes pela melancieira; no solo com 3% de matéria orgânica os melhores resultados corresponderam à dose de K₂O de 15 kg ha⁻¹ e para 6% entre 11 e 13 kg ha⁻¹.



INTRODUCTION

The mineral nutrition of watermelon [*Citrullus lanatus* (Thunb.) Matsum. & Nakai] is one of the factors that mostly contribute the most to the increase in yield and production quality of this crop, which stands out for exporting large amounts of nutrients, and potassium is the nutrient most extracted from 45 to 65 days after transplanting (Gonsalves et al., 2011; Almeida et al., 2012).

The adequate supply of K to watermelon increments the contents of the element in leaf dry matter and stimulates the absorption of other essential nutrients (El-Bassiony et al., 2012). For this, Cavalcanti (2008) recommends doses between 30 and 60 kg ha⁻¹ of K₂O, in the state of Pernambuco. In other northeastern states, such as Paraíba, the manuals of recommendation are scarce or outdated and become an obstacle for the expansion of local crops, warning for the necessity of studies with fertilization in local crops.

Besides mineral fertilization, the supply of organic matter to the soil is of great importance for the cultivation of watermelon and other vegetables, especially in sandy soils of arid regions that have low contents, because the climate conditions favor the acceleration of oxidation of soil organic matter (Nicolae et al., 2014).

Most producers of vegetables in the state of Paraíba, according to Silva et al. (2011), use cattle manure as the only source of nutrient for the crops, which means that, besides mineral fertilization, it is necessary to also invest in studies with doses of organic matter, because the manures are in many cases the only sources available to family farmers.

This study aimed to evaluate the leaf composition of macronutrients in watermelon plants cultivated in soil with doses of potassium and cattle manure.

MATERIAL AND METHODS

The experiment was carried out at the settlement 'Campo Comprido', in Patos, PB, Brazil, from March to June 2012. The climate of the region, according to Köppen's classification, is BSh, semiarid, with mean annual temperatures above 25 °C and mean annual rainfall below 1000 mm, with irregular rains during the rainy period. In 2012, the annual rainfall was 221 mm in the experimental area. The soil in the experimental area was classified as Fluvisol Neosol.

Before the experiment, soil samples were collected in the layer of 0-20 cm for chemical and physical characterization (Table 1) according to the methodologies suggested by EMBRAPA (2011).

The experimental design was randomized blocks with three replicates in a 3 × 5 + 1 factorial arrangement, referring to the addition of three doses of cattle manure (0.0; 1,100 and 2,520 g hole⁻¹) to increase the organic matter content of the soil, from 0.67% to 3.0 and 6.0%, five doses of K₂O in the form of potassium chloride (0.0; 7.5; 15.0; 22.5 and 30.0 kg ha⁻¹) as suggested by Cavalcanti (2008), and an additional treatment without fertilization, as commonly performed in the region. The experimental unit consisted of 21 plants per plot, distributed in three rows of seven plants.

The cattle manure doses were applied as basal fertilization during the opening and preparation of the holes, 30 days

Table 1. Soil chemical and physical characterization in the layer of 0-20 cm

Chemical attributes		Physical attributes	
pH H ₂ O (1:2.5)	7.02	Coarse sand (g kg ⁻¹)	312
P (mg dm ⁻³)	51.0	Fine sand (g kg ⁻¹)	475
K ⁺ (cmol _c dm ⁻³)	0.40	Silt (g kg ⁻¹)	137
Na ⁺ (cmol _c dm ⁻³)	0.30	Clay (g kg ⁻¹)	76
H ⁺ +Al ³⁺ (cmol _c dm ⁻³)	0.33	Dispersed clay (g kg ⁻¹)	13
Al ³⁺ (cmol _c dm ⁻³)	0.00	Degree of flocculation (%)	82.9
Ca ²⁺ (cmol _c dm ⁻³)	2.25	Dispersion index (%)	17.1
Mg ²⁺ (cmol _c dm ⁻³)	1.00	Soil density (kg dm ⁻³)	1.53
SB (cmol _c dm ⁻³)	3.93	Particle density (kg dm ⁻³)	2.67
CEC (cmol _c dm ⁻³)	4.26	Total porosity (m ³ m ⁻³)	0.43
V (%)	92.25		
SOM (g kg ⁻¹)	6.7	Textural class	Sandy

SB = Na⁺ + K⁺ + Ca²⁺ + Mg²⁺; CEC = SB + (H⁺ + Al³⁺); V = (100 × SB/CEC); SOM - Soil organic matter

before sowing. The holes were open with dimensions of 0.20 x 0.20 x 0.30 m, volume of 12 dm³ and spacing of 2.0 × 2.0 m. The variety 'Crimson Sweet' was selected for cultivation because of its acceptance in the regional market.

According to EMBRAPA (2011), the cattle manure showed the following chemical composition: pH = 7.90; P = 1003 mg dm⁻³; K⁺ = 3.81 cmol_c dm⁻³; Na⁺ = 0.30 cmol_c dm⁻³; H⁺+Al³⁺ = 0.57 cmol_c dm⁻³; Al³⁺ = 0.0 cmol_c dm⁻³; Ca²⁺ = 6.90 cmol_c dm⁻³; Mg²⁺ = 3.50 cmol_c dm⁻³ and OM = 38.86 % (388.6 g kg⁻¹).

The cattle manure doses were obtained using the following expression:

$$D_{CMA} = \frac{[(D_{OMA} - D_{OME}) \times Vc \times ds]}{OMCM} \quad (1)$$

where:

- D_{CMA} - dose of cattle manure to be applied per hole, g hole⁻¹;
- D_{OMA} - dose of organic matter to be achieved in the soil, g kg⁻¹;
- D_{OME} - dose of organic matter existing in the soil, g kg⁻¹;
- Vc - mean volumetric capacity of the hole, 12 dm³;
- ds - soil density, 1530 g dm⁻³; and,
- OMCM - organic matter content existing in the cattle manure, 388.6 g kg⁻¹.

The doses of K₂O in the form of potassium chloride were fractionated as 0, 25, 50, 75 and 100% of the maximum dose (30 kg ha⁻¹) recommended by Cavalcanti (2008) for watermelon in soil with K contents above 0.30 cmol_c; thus, 0.0, 7.5, 15, 22.5 and 30 kg ha⁻¹ of K₂O were provided at 40 days after seedlings emergence.

All treatments, except the additional, received nitrogen fertilization (120 kg ha⁻¹) in the form of urea, divided into two applications, 30 and 90 kg ha⁻¹ of N, at 20 and 40 days after seedlings emergence (Cavalcanti, 2008). No phosphate fertilization was applied, due to the high values observed in the soil and in the cattle manure.

At sowing, three seeds were planted per hole and, after emergence, when plants showed three pairs of permanent leaves, thinning was performed, leaving only the most vigorous plant per hole.

Irrigation from sowing to emergence was daily performed through sprinklers, maintaining the soil with moisture

content adequate for the germination process. From emergence to fruiting, irrigation was performed using the conventional sprinkler method, supplying every 48 h a water depth equal to the reference evaporation obtained by the product of Class A pan evaporation and the factor 0.75, as suggested by Andrade et al. (2013).

At the beginning of fruiting, 25 leaves (5th healthy leaf counted from the apex of the branch) were collected per plot, disregarding the apical tuft, as recommended by Trani & Raji (1997). After the samples were washed in tap water and submersed in deionized water, the material was placed in paper bags, dried in a forced-air oven at temperature of 65 °C for 72 h and ground in a Wiley-type mill (TE-650) using a 20-mesh sieve. Leaf dry matter was analyzed for: total N, determined through the micro-Kjeldahl method (sulfuric digestion); P, through colorimetry of metavanadate; K, through flame emission photometry; Ca and Mg, through atomic absorption spectrophotometry; and S, through gravimetry of barium sulfate (Malavolta et al., 1997).

The data were subjected to analysis of variance by F test; the means referring to cattle manure doses were compared by Tukey test at 0.05 probability level and those referring to K doses by regression. The analysis of contrasts between fertilized treatments and the additional treatment was performed through the Dunnett's test at 0.05 probability level using the statistical program SAS.

RESULTS AND DISCUSSION

The interaction between doses of K and cattle manure did not have significant effects on leaf N content; however, the mean contents observed in Table 2 are within the interval of 25-50 g kg⁻¹, considered by Trani & Raji (1997) as adequate for watermelon. Even considering that manure is a source of N to plants, the absence of significance between the doses of this input for the N contents of the plants can be explained by the supply of 120 kg ha⁻¹ of N in the form of urea in total area, which resulted in equalization of the contents in the plants.

In the treatment with supply of 1,100 g of cattle manure, the increase in K₂O doses promoted linear increment of 0.0263 g kg⁻¹ in leaf P content, from 4.8 to 5.6 g kg⁻¹ of leaf dry matter, which represents an increment of 16.5% between plants in soil without and with the highest dose of K₂O (Figure 1).

This increment is a response of the stimulating action of K in the release of P from the soil, which was also reported by El-Bassiony et al. (2012), who observed that K doses in the soil stimulate P absorption in watermelons and pumpkins.

Table 2. Mean contents of nitrogen (g kg⁻¹) in the leaf dry matter of watermelon cultivated in soil with potassium and cattle manure

K ₂ O dose (kg ha ⁻¹)	Cattle manure (g hole ⁻¹)		
	0	1,100	2,520
0.0	44.3	47.3	45.5
7.5	45.6	45.6	45.7
15.0	47.3	44.9	47.2
22.5	46.7	42.2	47.8
30.0	44.2	44.0	44.7
Mean	45.6	44.8	46.2

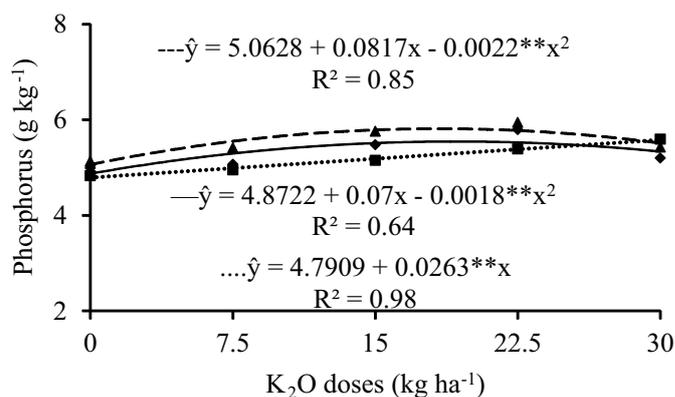


Figure 1. Leaf contents of phosphorus in watermelon cultivated in soil with potassium fertilization, without - 0 (—) and with 1,100 (...) and 2,520 g hole⁻¹ of cattle manure (---)

In the treatments without and with addition of 2,520 g of cattle manure, leaf P contents were increased to 5.55 and 5.82 g kg⁻¹ of P for the maximum estimated doses of 19.4 and 18.6 kg ha⁻¹ of K₂O (Figure 1). According to Trani & Raji (1997), leaf P contents varying between 3.0 and 7.0 g kg⁻¹ are adequate for the watermelon crop. It is observed, based on the amplitude, that the plants cultivated in the soil without the addition of cattle manure (dose of 0.0) and K₂O were adequate supplied in P.

The increment in leaf P accumulation was more pronounced in the treatments with the highest dose of cattle manure, 2,520 g hole⁻¹, probably due to the higher supply of P with the highest dose of manure and the action of the organic acids produced during the decomposition of organic matter, which blocks P absorption sites in the soil, decreasing the fixation by the soil (Guppy et al., 2005).

This information is also consistent with Abul-Soud et al. (2010), in the cucumber crop (*Cucumis anguria* L.), Bindiya et al. (2012) and Santos et al. (2012), who reported increments of P in the leaf tissue of pumpkin (*Cucurbita pepo* L.) due to doses of organic inputs applied to the soil.

The adequate supply to plants can be a response of the high content of the nutrient in the soil (51 mg dm⁻³) as also observed by Geleta et al. (2011) in watermelon plants cultivated in soils with high P contents.

Leaf K contents did not differ as a function of the doses of cattle manure and K₂O added to the soil, but the mean contents are within the range of 20 to 60 g kg⁻¹ (Table 3) and, according to Trani & Raji (1997), plants were balanced with respect to the macronutrient.

Table 3. Mean contents of potassium (g kg⁻¹) in the leaf dry matter of watermelon cultivated in soil with doses of potassium and cattle manure

K ₂ O dose (kg ha ⁻¹)	Cattle manure (g hole ⁻¹)		
	0	1,100	2,520
0.0	42.4	39.2	40.9
7.5	39.5	38.5	43.4
15.0	39.2	39.8	42.5
22.5	39.0	41.0	40.9
30.0	42.1	41.1	40.2
Mean	40.4	39.9	41.6

The absence of significant difference of K contents in leaf dry matter, associated with the adequate nutrition of the plants, means that the contents existing in the soil met the requirement of the crop. Despite the absence of significant differences, the previous supply of this element cannot be neglected, since the soil in the area is sandy and, under irrigation regime, the suppression of K could cause deficiency of this nutrient due to losses through leaching (Nicolae et al., 2014).

Even considering the plants in the treatments without K₂O and cattle manure had contents sufficient for their demand, the watermelon crop, for being a plant that demands high amounts of K (Almeida et al., 2012), require the maintenance of sufficient levels of the element in the soil during its cycle, which justifies the recommendation of K by Cavalcanti (2008) even in soil with high contents of the nutrient.

In plants of the treatments without cattle manure, leaf Ca contents linearly increased from 15.53 to 22.1 g kg⁻¹, an increment of 42.31% between plants without and with the highest dose of K₂O (Figure 2). This result differs from those in the literature, in which the addition of K to the soil inhibits the availability of Ca to plants (Silva & Trevizam, 2015).

In the treatments with 1,100 g hole⁻¹, represented by the equation $\hat{y} = 16.44 + 0.8281x - 0.0277x^2$ ($R^2 = 0.52$) and 2,520 g hole⁻¹ of cattle manure (Figure 2), the increment in K doses increased the values of Ca in plant leaves to contents of 22.5 and 22.8 g kg⁻¹, respectively, at the maximum estimated K₂O doses of 14.9 and 13.1 kg ha⁻¹.

The behavior of the data is similar to those reported by Nascimento et al. (2015) for watermelon and Santos et al. (2012) for pumpkin, a plant of the same family of watermelon, who reported increments in leaf Ca contents due to the increase in doses of organic materials in the soil.

The decrease in Ca in the treatments with K₂O doses above the maximum estimated doses can be due to the competitive inhibition between K and Ca in the exchange sites of the soil (Silva & Trevizam, 2015). Still in agreement with the previously mentioned authors, when there are high levels of K in the soil, the plant grows more, causing reduction in the contents of Ca due to the dilution effect.

The leaf Ca contents of 22.1, 22.5 and 22.8 g kg⁻¹, respectively, in plants without and with the addition of cattle manure, to increase the content of soil organic matter from 0.67% to 3.0

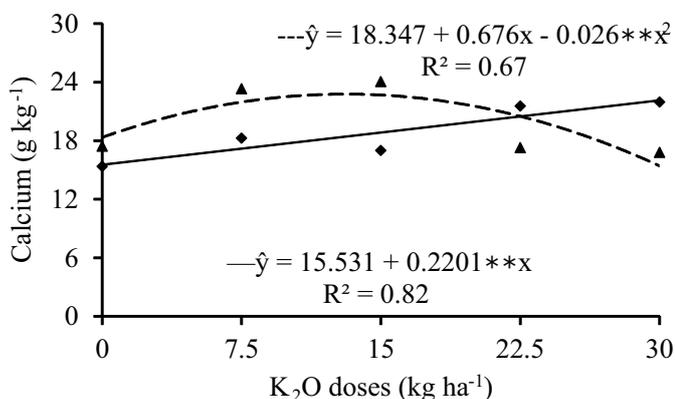


Figure 2. Leaf contents of calcium in watermelon cultivated in soil with K₂O doses, without - 0 (—) and with 2,520 g hole⁻¹ of cattle manure (---)

and 6.0%, are below the lower critical limit that meets the requirement of watermelon, which oscillates between 25 and 50 g kg⁻¹ (Trani & Raij, 1997).

In the treatments without manure (0 g hole⁻¹) and with the dose of 1,100 g hole⁻¹, leaf Mg contents did not fit to any mathematical model as a function of the K₂O doses, with mean contents of 5.26 and 5.97 g kg⁻¹, respectively (Figure 3).

In the treatment with 2,520 g hole⁻¹ of cattle manure, the increment in K₂O doses caused reduction in Mg accumulation in the leaf dry matter of the plants. In spite of that, the mean content of Mg accumulated in the leaves (6.62 g kg⁻¹) was numerically higher than those observed in the treatments with 0.0 and 1,100 g hole⁻¹ of cattle manure. As observed for the Ca content, the absorption of Mg was also inhibited by the increment in K doses.

Similar behavior was reported by Santos et al. (2012), studying doses of organic inputs applied to the soil on the leaf Mg contents in pumpkin. Based on the results in all situations, the contents of Mg are within the range of 5-12 g kg⁻¹ established as adequate for the watermelon crop (Trani & Raij, 1997)

Due to the increase in the doses of cattle manure, the contents of S fitted to a quadratic model of polynomial regression (Figure 4). The supply of the doses of 0.0 g hole⁻¹ ($\hat{y} = 2.41708 + 0.02003x - 0.00053x^2$, $R^2 = 0.58$), 1,100 g hole⁻¹ ($\hat{y} = 2.49128 + 0.02932x - 0.00087x^2$, $R^2 = 0.53$) and 2,520 g hole⁻¹ of cattle manure, associated with doses of 18.9, 16.8

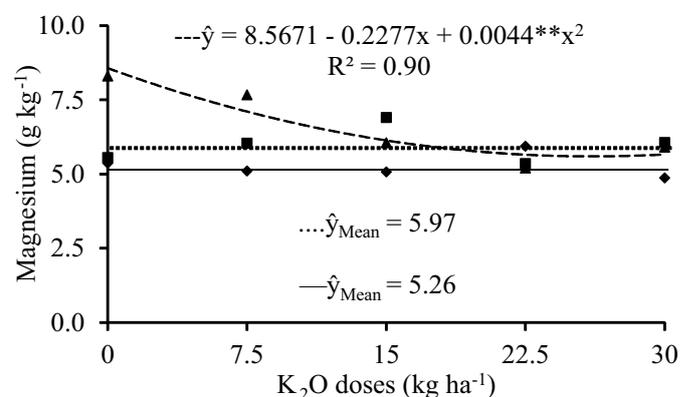


Figure 3. Leaf contents of magnesium in watermelon cultivated with K₂O doses, without - 0 (—), and with 1,100 (....) and 2,520 g hole⁻¹ of cattle manure (---)

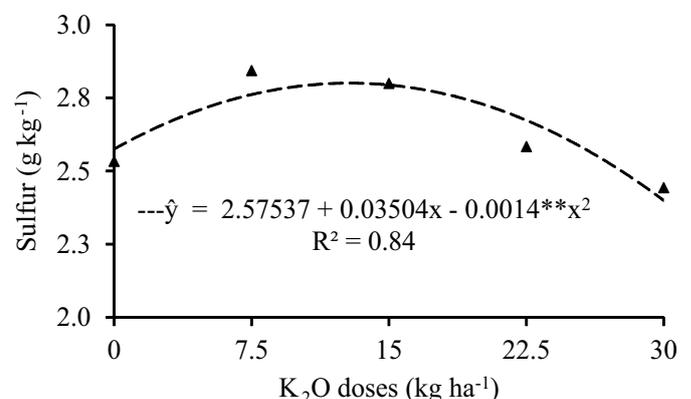


Figure 4. Leaf contents of sulfur in watermelon cultivated in soil with doses of K₂O and 2,520 g hole⁻¹ of cattle manure (---)

and 12.8 kg ha⁻¹ of K₂O, was responsible, respectively, for the highest contents of S 2.60, 2.73 and 2.79 g kg⁻¹ (Figure 4).

The superiority of S contents in the treatments with higher amount of cattle manure, in relation to the lower doses, is due to the fact that the manure is source of S to the plants and, therefore, higher doses contribute with greater increments in the availability of the element in the soil to the plants (Higashikawa et al., 2010).

Watermelon plants, including those in treatments without the addition of cattle manure, showed S contents in the range of 2.0 to 3.0 g kg⁻¹, an indication that they were nutritionally balanced with respect to this element (Trani & Rajj, 1997).

In relation to the test of contrasts between the additional treatment (without fertilizer) and the treatments with fertilization, it is observed that, except for Ca, the leaf contents of the other macronutrients were higher in the treatments that received manure and K (Table 4).

The manure, besides providing elements in small amounts to the soil, especially N, P and S, increases the efficiency of mineral fertilization and, therefore, the availability of nutrients to plants (Higashikawa et al., 2010).

For the contents of N and K in the leaf tissue, the superiority is mainly due to the supply of urea and potassium chloride. The inferiority of Ca contents in the treatments with K₂O and manure strengthens the hypothesis of competition between these two elements, compromising the absorption of Ca (Silva & Trevizam, 2015).

Table 4. Mean contents of N, P, K, Ca and S in the leaf dry matter of watermelon plants fertilized with cattle manure and potassium, for the test of contrasts between the factorial and the additional treatment

Treatments	N	P	K	Ca	S
	g kg ⁻¹				
Fertilizers	45.5 a	5.3 a	40.6 a	19.4 b	2.60 a
Additional	41.6 b	4.9 b	38.7 b	24.8 a	2.43 b

Means followed by the same letters in columns do not differ by the Dunnett's test at 0.05 probability level

CONCLUSIONS

1. The supply of cattle manure enhances the absorption of macronutrients by watermelon plants.
2. The dose of 2,520 g hole⁻¹ of cattle manure promoted better results when associated with 11 and 13 kg ha⁻¹ of K₂O.

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