Watermelon (*Citrullus lanatus* Thunb.) Production as Affected by Soil Potassium Fertilizer and Livestock Manure

Nascimento Jose Adeilson Medeiros do[1], Souto Jacob Silva[2], Cavalcante Lourival Ferreira[3], Pereira Walter Esfrain[3]

[1]*Instituto Federal de Educação, Ciência e Tecnologia, Campus Tianguá, Rodovia CE 187, S/N, Bairro Aeroporto, CEP:62320-000 Tianguá/CE, Correo electrónico:* adeilson.nascimento@ifce.edu.br
[2]*Universidade Federal de Campina Grande - UFCG / Centro de Saúde e Tecnologia Rural - CSTR Avenida Universitária S/N - Bairro Santa Cecília, CEP:58708-110, Patos/PB.*
[3]*Universidade Federal da Paraíba/Centro de Ciências Agrárias - Campus II, CEP: 58397-000, Areia, PB - Rodovia BR 079 - km 12*.

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Summary

Organic-mineral nutrient availability in soils cultivated with vegetables is essential for a satisfactory and economically viable production, including the watermelon (*Citrullus lanatus*). The aim of this experiment was to evaluate the influence of the addition of livestock manure to the soil with and without potassium on watermelon (cv. Crimson Sweet) production in Paraiba, Brazil. The treatments were arranged in a design of randomized blocks, with four replications, with a factorial arrangement 2 × 5 + 1, in relation to the absence and presence of potassium, five levels of livestock manure (0, 360; 1.080; 1800 and 2510 g hole^{-1}) in the soil with nitrogen fertilization, and a control treatment (without cattle manure or mineral fertilizers). The number of fruits per plant, the average weight of the fruits per plant, and the yield were evaluated. The plants responded positively to the application of livestock manure to the soil, but the results were higher in combination with potassium fertilization. Productivity increased in treatments in which potassium was supplied to the soil in addition to a maximum of 1124 g hole^{-1} of cattle manure. Half of the previously recommended level of potassium supply was enough to raise the productivity of watermelon in the region.

Keywords: *Citrullus lanatus*, organic matter, chemical fertilization

La producción de sandía (*Citrullus lanatus* Thunb.) en suelo fertilizado con potasio y estiércol de ganado

Resumen

La disponibilidad de nutrientes orgánicos y minerales en suelos cultivados con hortalizas es esencial para una producción satisfactoria y económicamente viable, incluyendo la de sandía (*Citrullus lanatus*). El objetivo de este ensayo fue evaluar la influencia del agregado de estiércol al suelo con y sin potasio en la producción de sandía (cv. Crimson Sweet) en Paraíba, Brasil. Los tratamientos se dispusieron en un diseño de bloques al azar, con cuatro repeticiones, con un arreglo factorial 2 x 5 + 1, en relación con la ausencia y presencia de potasio, cinco dosis de estiércol de ganado (0; 360; 1080; 1800 y 2510 g por hoyo de plantación) en el suelo con fertilización nitrogenada, y un testigo (sin estiércol y sin agregado de fertilizantes minerales). Se evaluó el número de frutos por planta, el peso promedio de frutos por planta y el rendimiento. Las plantas respondieron positivamente a la aplicación de estiércol al suelo, pero los resultados fueron más altos en los tratamientos en combinación con fertilización con potasio. En los tratamientos con suministro de potasio en el suelo los niveles de materia orgánica con mayor productividad fueron de alrededor de 1124 g por hoyo de plantación. El suministro de la mitad de la dosis previamente recomendada de potasio fue suficiente para elevar la productividad de sandía en la región.

Palabras clave: *Citrullus lanatus*, materia orgánica, fertilización química

Introduction

Watermelon [*Citrullus lanatus* (Thunb.) Matsum. & Nakai] is a Cucurbitaceae, originated in the tropical regions of Africa. It is cultivated throughout most of Brazil due to favorable soil and climatic conditions (Tosta et al., 2010). The current watermelon average yield in Brazil is 23.5 Mg ha^{-1}. The midwestern and southeastern regions are the main production areas in the country, and the states of Ceará and Goiás are the major producers (IBGE, 2013).

According to a recent agricultural census, 603,015 Mg of watermelon were produced in north-eastern Brazil in an area of 28,436 ha, representing an average yield of 21.3 Mg ha^{-1}. Paraiba State produced 5,100 Mg in an area of 266 ha, with an average yield of 19.2 Mg ha^{-1} (IBGE, 2013). However, even under favorable climatic conditions for the cultivation of watermelon, primarily in semiarid areas, Paraiba State is eighth in volume produced and seventh in earnings among the north-eastern states. Therefore, watermelon cultivation should be encouraged through subsidies and government investment in research that aims to improve cultural practices and to provide information to producers for strengthening cultivation to increase earnings.

Among the factors contributing to the low productivity of the vegetables, including watermelon, there is lack of sufficient information on crop management by farmers, especially in respect to mineral and organic fertilizers (Leão et al., 2008). Fertilization is a crucial factor for short-cycle vegetable crops with a high demand for nutrients like potassium and nitrogen (Andrade Junior et al., 2006). Some studies show that watermelon is highly demanding of potassium, the nutrient that is the most absorbed and exported to the fruits during the productive phase (Grangeiro & Cecílio Filho, 2006; Aguyoh et al., 2011).

There are concerns about the use of chemical fertilizers, but supplying organic matter to the soils, especially manure, promotes growth of vegetables due to its positive effects on soil chemical, physical and biological properties. These effects include increasing the supply and availability of nutrients (Higashikawa, Silva & Bettiol, 2010; Müller et al., 2014; Silva & Menezes, 2007), improving water storage and soil drainage (Hussein, 2009), and improving the efficiency and utilization of mineral fertilizers (Guppy et al., 2005). However, elevated levels of manure and other organic materials in the soil can lead to an imbalance of nutrients, and to diseases resulting from excessive soil moisture (Oliveira et al., 2007).

The provision of adequate levels of manure to the soil, alone or in combination with chemical fertilizers, had resulted in increased yields of watermelon and other vegetable crops like pumpkin, cucumber, and gherkin (Abul-Soud, El-Ansary & Hussein, 2010; Leão et al., 2008; Oliveira et al., 2009; Onyia et al., 2012; Sarhan, Mohammed & Teli, 2011). However, because of the environmental specific conditions in each region, the sources and amounts of organic matter applied to the soil aiming at the increase of the production should be studied to prevent damage to the environment and crop failure. The aim of this experiment was to evaluate the influence of the addition of various levels of livestock manure to the soil, with and without potassium fertilization on watermelon production.

Material and Methods

The experiment was conducted on Campo Comprido (7°04'27.1"S and 37°19'05.2"W), Patos City (Altitude = 242 m), Paraiba State, Brazil, from October to December 2012. According to Koeppen classification, the region's climate is type BSh, semiarid, with annual average temperatures exceeding 25 °C, average annual rainfall < 1000 mm y^{-1}, and irregular rainfall (Ministério da Agricultura, 1972). The local soil was classified as NEOSSOLO Fluvico (Santos et al., 2013). Soil samples were collected at 20 cm depth to determine physical and chemical soil characteristics according to the procedures proposed by EMBRAPA (2011) (Table 1).

Treatments were arranged in a randomized block design with four replications in a factorial scheme 2 × 5 + 1, referring to absence and presence (15 kg ha^{-1} K_2O) of potassium fertilization and five doses of livestock manure (0, 360; 1080; 1800 and 2510 g hole^{-1}) in soil with nitrogen fertilization, and an absolute control treatment (no organic nor mineral fertilizer). The plots were composed of three lines with seven plants. All plants of the plots were considered for evaluation of production.

For treatments with potassium, the dose (15 kg ha^{-1} K_2O) was defined according to the recommendation of Agronomic Institute of Pernambuco (IPA, 2008) for watermelon crops. A dose of 30 kg ha^{-1} K_2O is recommended in soils with potassium content > 0.30 cmol$_c$ dm^{-3} (IPA, 2008), but as the experimental soil area had 0.40 cmol$_c$ dm^{-3}, half the recommended level was provided. Potassium was supplied in a single application, 40 days after germination, using potassium chlorate (KCl). In addition to the ten treatments with the 2 x 5 combinations between potassium and cattle manure, an absolute control treatment with no mineral no organic fertilizer was included. The treatments with manure and

Table 1. Chemical and physical soil attributes of the soil at 20 cm depth.

Chemical attributes		Physical attributes	
pH H_2O (1:2,5)	6,7	Gross sand (g kg^{-1})	30
P (mg dm^{-3})	58,59	Fine sand (g kg^{-1})	481
K^+ ($cmol_c$ dm^{-3})	0,40	Silt (g kg^{-1})	364
Na^+ ($cmol_c$ dm^{-3})	0,37	Clay (g kg^{-1})	125
H^++Al^{3+} ($cmol_c$ dm^{-3})	1,07	Dispersed clay (g kg^{-1})	51
Al^{3+} ($cmol_c$ dm^{-3})	0,00	Flocculation index (%)	59,2
Ca^{2+} ($cmol_c$ dm^{-3})	3,25	Soil density (g cm^{-3})	1,52
Mg^{2+} ($cmol_c$ dm^{-3})	1,55	Density of particle (g cm^{-3})	2,74
SB ($cmol_c$ dm^{-3})	5,57	Porosity total (m^3 m^{-3})	0,44
CTC ($cmol_c$ dm^{-3})	6,64		
V(%)	83,9		
m (%)	0,00		
PST (%)	5,57		
O.M. (g kg^{-1})	7,5	Textural classification:	Sandy

SB = Na^+ + K^+ + Ca^{2+} + Mg^{2+}; CTC = SB + (H^+ + Al^{3+}); V = (100 x SB/CTC); m = (100 x Al^{3+}/CTC - Al^{3+}); PST= (100 x Na^+/CTC); O.M. = organic matter.

potassium also received nitrogen in the form of urea (45 % N) at 26.68 and 80 g plant-1 (66,7 and 200,1 kg ha-1) at 20 and 40 days after germination, respectively, as recommended by IPA (2008). Phosphorus was not supplied because the soil had very high phosphorus content (Table 1).

The manure used in the experiment was chemically characterized (Table 2). Manure was applied 30 days before sowing to increase the content of soil organic matter from 0.75 % (7.5 g kg^{-1}), the content prior to the experiment (Table 1), to 1.5, 3.0, 4.5, and 6.0 % (7.5; 15; 30; 45 and 60 g kg^{-1}). Considering that only part of the cattle manure is carbon (380.54 g kg^{-1}) the doses (g $hole^{-1}$) were obtained using the following expression:

$$D_{CMA} = [(D_{OMA} - D_{OME}) \times Vc \times Ds] / OMCM$$

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, 7.5 g kg^{-1} (Table 1);

Vc - mean volumetric capacity of the hole, 12 dm^3 (0.20 m × 0.20 m × 0.30 m);

ds - soil density, 1520 g dm^{-3};

OMCM - organic matter content in the cattle manure, 380.54 g kg^{-1} (Table 2).

The watermelon cultivar used for the experiment was 'Crimson Sweet'. Planting holes (0.20 m × 0.20 m × 0.30 m) were dug 30 days before seeding, spaced 2.0 m × 2.0 m. Three seeds were sown in each hole, and when plants had three pairs of leaves, permanent thinning was performed leaving only one plant per hole. The experiment was irrigated daily from sowing to germination (eight days), and every

Table 2. Chemical attributes of the manure used in the experiment.

pH	P	K^+	Na^+	H^+ + Al^{3+}	Al^{3+}	Ca^{2+}	Mg^{2+}	O.M.	C/N ratio
	mg dm^{-3}					$cmol_c$ dm^{-3}			g kg^{-1}
7,7	912.8	1954.79	4.72	0.58	0.0	6.70	4.80	380.54	27/1

O.M. = organic matter.

two days from germination to fruiting (70-75 days) by sprinkler irrigation, providing the equivalent of 24 L plant^{-1} day^{-1} as recommended by Carvalho (2005). After harvest onset, fruits were collected once or twice a week, and counted and weighed to determine the cumulative number of fruits per plant, average fruit weight (kg) and productivity (Mg ha^{-1}).

Data were subjected to analysis of variance (ANOVA). Means values referring to potassium fertilization were compared by Tukey's test (5 % probability level) and means referring to cattle manure were submitted to regression tests. Contrast analysis and Dunnett's test ($p < 0.05$) between the treatments with fertilization (livestock manure and mineral inputs) and control treatment (without mineral fertilizer or manure) were performed.

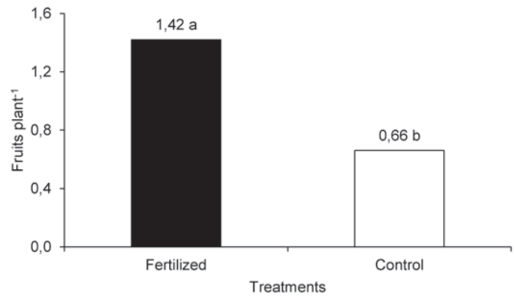

Figure 1. Number of watermelon fruits per plant in soil fertilized with potassium and livestock manure (factorial, ■) and without fertilization organic or chemical (control, □). Different letters on top of each column means significant differences ($p < 0.05$) according to Tukey's test.

Results and Discussion

The average per-plant fruit production was not affected by manure and potassium supply to the soil according to ANOVA analysis ($p < 0.05$). There was a significant effect for the contrast between treatments with potassium fertilization and livestock manure against the control treatment (Figure 1). The average number of fruits per plant was 0.66 in the treatments without mineral fertilizers and manure (control treatment) and 1.42 fruits in the treatments with combinations manure x potassium fertilizer, that is, a superiority of 115 % in relation to the control treatment.

The supply of potassium and nitrogen to the soil in addition to manure stimulated fruit production. These two nutrients are required in large amounts by watermelon (Grangeiro & Cecílio Filho, 2006), and therefore plants responded positively to their supply. Leão et al. (2008) evaluated the effects of applying manure and NPK fertilizer on watermelon production, and obtained 1.15 fruits per plant by providing 9 L manure per hole, treatments with fertilization. An increased number of fruits per plant due to increased soil organic matter was recorded in other cucurbits, such as gherkin (*Cucumis anguria* L.) (Oliveira et al., 2009) and cucumber (*Cucumis sativus* L.) (Hussein, 2009; Onyia et al., 2012). In pumpkin plants, Sarhan, Mohammed & Teli (2011) found that sheep manure significantly increased the number of fruits. Comparing the treatments with chemical and organic fertilizers with the control treatment, treatments 1, 4, 8 and 10 showed no significant difference (Table 3).

Table 3. Comparison between fertilized treatments and control by the Dunnet's test (significant at the 0.05 level) for fruit values per plant of watermelon (kg fruits plant^{-1}).

Treatments comparison	Difference between means	Simultaneous 95 %	Confidence limits
7 (0.0 kg ha^{-1} K_2O + 1800 g hole^{1} CM) X 11 (Control)	1.0635	0.4148	1.7102***
3 (0.0 kg ha^{-1} K_2O + 360 g hole^{1} CM) X 11 (Control)	1.0000	0.3523	1.6477***
2 (15 kg ha^{-1} K_2O + 360 g hole^{1} CM) X 11 (Control)	0.9063	0.2586	1.5539***
9 (0.0 kg ha^{-1} K_2O + 2520 g hole^{1} CM) X 11 (Control)	0.8438	0.1961	1.4914***
6 (15 kg ha^{-1} K_2O + 1080 g hole^{1} CM) X 11 (Control)	0.8125	0.1648	1.4602***
5 (0.0 kg ha^{-1} K_2O + 1080 g hole^{1} CM) X 11 (Control)	0.7188	0.0711	1.3664***
4 (15 kg ha^{-1} K_2O + 360 g kg^{1} CM) X 11 (Control)	0.6250	-0.0227	1.2727
1 (0.0 kg ha^{-1} K_2O + 0.0 g hole^{1} CM) X 11 (Control)	0.5938	-0.0539	1.2414
8 (15 kg ha^{-1} K_2O + 1800 g hole^{1} CM) X 11 (Control)	0.5313	-0.1164	1.1789
10 (15 kg ha^{-1} K_2O + 2520 g hole^{1} CM) X 11 (Control)	0.5313	-0.1164	1.1789

CM = Cattle manure; Minimum Significant Difference = 0.6477 kg fruits plant^{-1}; *** Significant comparisons ($p < 0.05$).

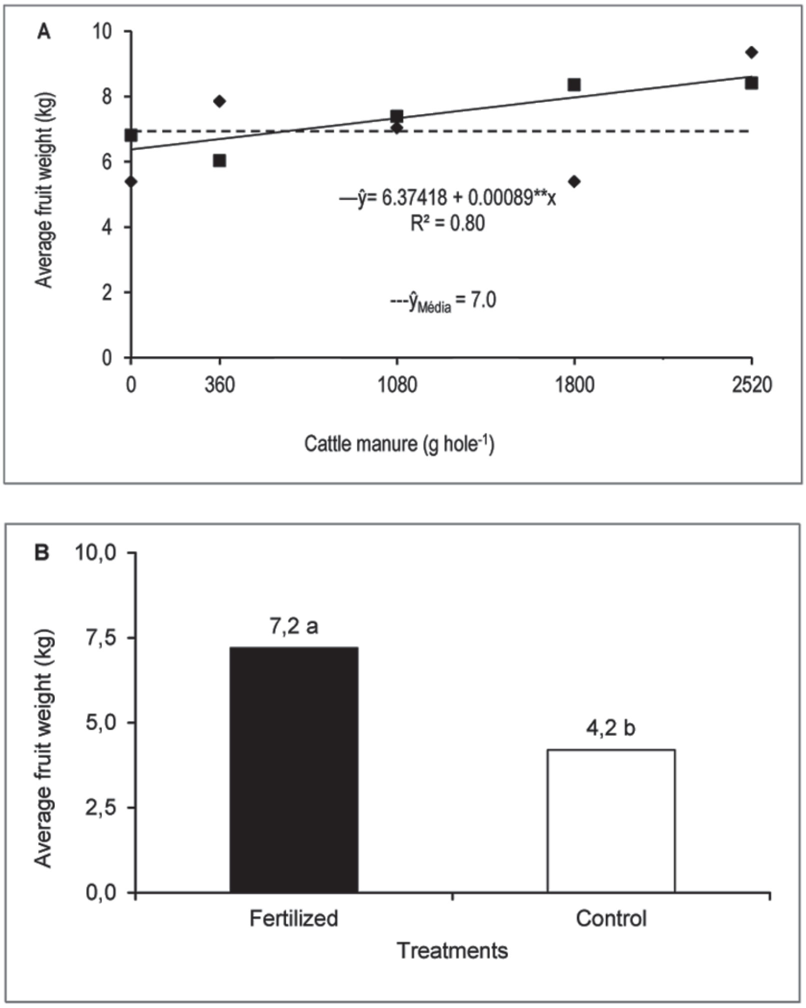

Figure 2. (A) Average fruit weight of watermelon cultivated under livestock manure levels in soil without (—) and with (- - -) potassium supply and (B) comparison between treatments with organic or mineral fertilization (■) and control treatment (☐). Different letters on top of each column mean significant differences ($p < 0.05$) according to Tukey's test.

The average weight of watermelon fruits was significantly influenced by manure and potassium supply (Figure 2A). For treatments without added potassium, regression models did not fit for organic amendment, with an average 7.0 kg fruit^{-1} across manure dosages. On the other hand, in treatments with potassium applied, a lineal relationship was established ($w = 6.3783 + 0.0277^{**}x$), where values increased from 6.37 to 8.6 kg fruit^{-1} in soil received the highest dose of manure (2520 g hole^{-1}), which means an increase of 35 % in absolute values.

Leão et al. (2008) also found that the average mass of watermelon fruits increased as increased manure in the soil, reaching 5.3 kg fruit^{-1} with 9 L manure per hole. In pumpkin experiments, Abul-Soud, El-Ansary & Houssein (2010) and Santos et al. (2012) also observed an increase in average fruit weight when levels of livestock manure and liquid pig manure were applied to the soil. However, melon plants growing in soils containing different sources and levels of organic matter including manure, Souza et al. (2008) found no significant differences in average fruit weight.

Mainly at levels above 720 g hole^{-1} manure, average fruit mass for potassium treatments was higher statistically than that observed in treatments without potassium (Figure 2A). This response may be due to the higher nutrient content associated with higher levels of organic matter (Galvão, Salcedo & Oliveira, 2008), and because potassium, applied as KCl, is the main nutrient responsible for fruit quality (Aguyoh et al., 2011).

Table 4. Comparison between fertilized treatments and control by the Dunnet's test (significant at $P < 0.05$) for average fruit weight of watermelon (kg $fruit^{-1}$).

Treatments comparison	Difference between means	Simultaneous 95 %	Confidence limits
9 (0.0 kg ha^{-1} K_2O + 2520 g $hole^{1}$ CM) X 11 (Control)	5.1501	3.1149	7.1853***
10 (15 kg ha^{-1} K_2O + 2520 g $hole^{1}$ CM) X 11 (Control)	4.2096	2.1745	6.2448***
8 (15 kg ha^{-1} K_2O + 1800 g $hole^{1}$ CM) X 11 (Control)	4.1513	2.1161	6.1864***
3 (0.0 kg ha^{-1} K_2O + 360 g $hole^{1}$ CM) X 11 (Control)	3.6470	1.6118	5.6822***
6 (15 kg ha^{-1} K_2O + 1080 g $hole^{1}$ CM) X 11 (Control)	3.1860	1.1508	5.2212***
5 (0.0 kg ha^{-1} K_2O + 1080 g $hole^{1}$ CM) X 11 (Control)	2.8385	0.8033	4.8736***
2 (15 kg ha^{-1} K_2O + 0.0 g $hole^{1}$ CM) X 11 (Control)	2.6129	0.5777	4.6481***
4 (15 kg ha^{-1} K_2O + 360 g $hole^{1}$ CM) X 11 (Control)	1,8244	-0.2108	3.8596
7 (0.0 kg ha^{-1} K_2O + 1800 g $hole^{1}$ CM) X 11 (Control)	1.1918	-0.8433	3.2270
1 (0.0 kg ha^{-1} K_2O + 0.0 g $hole^{1}$ CM) X 11 (Control)	1.1862	-0.8489	3.2214

CM = Cattle manure; Minimum Significant Difference = 2.03 kg $fruit^{-1}$; *** Significant comparisons ($p < 0.05$).

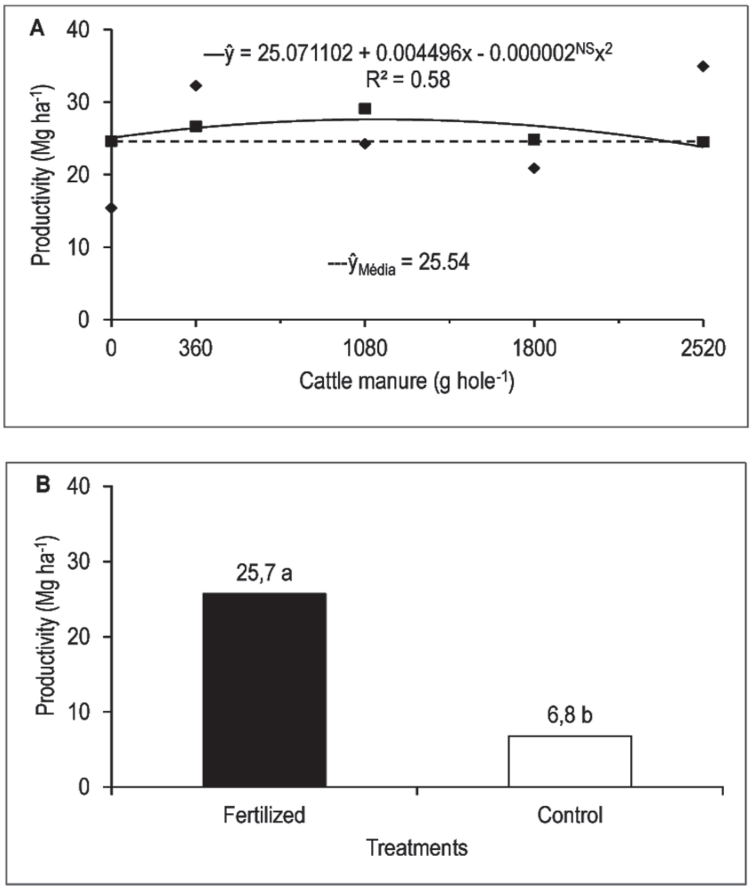

Figure 3. (A) Productivity of watermelon cultivated under livestock manure levels in soil without (—) and with (- - -) potassium supply and (B) comparison between treatments with organic or mineral fertilization (■) and control treatment (□). Different letters on top of each column mean significant Tukey's test differences ($p < 0.05$) according to Tukey's.

Contrast tests showed that an increase in fruit mass from 4.2 kg^{-1} (absolute control) to 7.2 kg^{-1} fruit in the treatments with manure and potassium, indicating a 71 % average increase in fruit weight in fertilized soil (Figure 2B). Alburquerque et al. (2012) found that the supply of livestock manure and mineral fertilizer significantly increased the average mass of watermelon fruits. Onyia et al. (2012) also observed an increase in average fruit weight of cucumber as receiving chemical and organic fertilizer.

Watermelon fruits cv. Crimson Sweet can reach usually 10 to 12 kg. However, fruits below 7 kg are preferred and achieve the best price in the market, which means that the fertilization treatments applied resulted in fruits with adequate weight for the market. According to the classification proposed by Carvalho (2005), watermelon fruits obtained in treatments with organic and mineral fertilizer could be classified as «first quality» as fruit weights were between 6 and 9 kg. Except for treatments 1, 4 and 7, other treatments showed a significant difference to the absolute control treatment (Table 4).

Productivity in treatments without potassium did not fit any mathematical model, and was thus represented by the mean value of 25.5 Mg ha^{-1} (Figure 3A). In treatments with added potassium, values were adjusted to a quadratic polynomial regression model (25.071102 + 0.004496x - 0.000002^{NS}x^{2}), with a maximum yield of 27.7 Mg ha^{-1} corresponding to 1124.0 g manure hole^{-1} (Figure 3A). Leão et al. (2008) obtained the maximum yield of 22.5 Mg ha^{-1} in watermelon fertilized with manure (0, 3, 6, and 9 L manure hole^{-1}) and NPK. Aguyoh et al. (2011), working with an organic compound (0, 1500, 3000, and 4500 g hole^{-1}) enriched with triple superphosphate and potassium nitrate, obtained a maximum yield of 28.63 Mg ha^{-1} related to the highest dose tested (4500 g hole^{-1}).

The contrast tests revealed a significant increase in productivity, from 6.8 Mg ha^{-1} in the absolute control to 25.7 Mg ha^{-1} in treatments with manure and mineral fertilization, 278 % productivity increase (Figure 3B). Yields in treatments with organic and mineral fertilizer is a response of nitrogen and potassium supply to plants, which resulted in an increase in the number and weight of fruits. In other cucurbits, productivity also increases with supply of organic and mineral fertilizers to the soil, as described for cucumber plants (Hussein, 2009; Onyia et al., 2012), gherkin (Oliveira et al., 2009), and pumpkin (Sarhan, Mohammed & Teli, 2011; Santos et al., 2012). Productivity was significantly higher in all treatments with fertilizers as compared to the control treatment (Table 5).

Conclusions

By raising the soil organic matter to about 3 %, the supply of 15 kg ha^{-1} potassium in Paraiba semiarid region significantly raises productivity above the regional average.

Table 5. Comparison between fertilized treatments and control by the Dunnet's test (significant at the 0.05 level) for productivity of watermelon (ton ha^{-1}).

Treatments comparison	Difference between means	Simultaneous 95 %	Confidence limits
9 (0.0 kg ha^{-1} K_2O + 2520 g hole^{1} CM) X 11 (Control)	56.292	42.150	70.433***
3 (0.0 kg ha^{-1} K_2O + 360 g hole^{1} CM) X 11 (Control)	50.916	36.775	65.058***
6 (15 kg ha^{-1} K_2O + 1080 g hole^{1} CM) X 11 (Control)	41.177	27.035	55.318***
4 (15 kg ha^{-1} K_2O + 360 g hole^{1} CM) X 11 (Control)	39.336	25.195	53.478***
10 (15 kg ha^{-1} K_2O + 2520 g hole^{1} CM) X 11 (Control)	35.786	21.644	49.927***
2 (15 kg ha^{-1} K_2O + 0.0 g hole^{1} CM) X 11 (Control)	35.629	21.488	49.770***
8 (15 kg ha^{-1} K_2O + 1800 g hole^{1} CM) X 11 (Control)	35.431	21.290	49.572***
5 (15 kg ha^{-1} K_2O + 1080 g hole^{1} CM) X 11 (Control)	34.895	20.753	49.036***
7 (15 kg ha^{-1} K_2O + 1800 g hole^{1} CM) X 11 (Control)	28.173	14.031	42.314***
1 (15 kg ha^{-1} K_2O + 0.0 g hole^{1} CM) X 11 (Control)	17.175	3.033	31.316***

CM = Cattle manure; Minimum Significant Difference = 14.141 ton ha^{-1}; *** Significant comparisons ($p < 0.05$).

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