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Nutrient contents and growth of corn fertigated with human urine and cassava wastewater

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ABSTRACT: This study aimed to evaluate the contents of macronutrients (NPK and S) and the growth of 'Potiguar' corn fertigated with human urine, cassava wastewater and their associations with NPK. The experiment was set up in greenhouse located on Campus I of Universidade Federal de Campina Grande. A completely randomized experimental design was used, consisting of eight treatments, corresponding to fertigation with mineral fertilizer NPK formula; organic, composed of yellow water, cassava wastewater and human urine associated with cassava wastewater; organomineral, composed of human urine associated with phosphorus and potassium, cassava wastewater associated with nitrogen and phosphorus and human urine associated with cassava wastewater and phosphorus, with five repetitions. At 50 days after sowing (DAS), plants were evaluated for the leaf NPK and S concentrations and growth variables: number of leaves, plant height, stem diameter, leaf area, fresh and dry mass of leaves, mass of stem and of shoots. Nitrogen and phosphorus concentrations and the growth variables number of leaves, plant height, fresh and dry mass of leaves, mass of stem and of shoot were influenced by fertigation with human urine, cassava wastewater concentrations and their associations with NPK. In the leaves of corn cultivar Potiguar the accumulated concentrations of N, P and K, at 50 DAS, varied in the sequence N > K > P. Human urine has potential as source of N in fertigation of corn and cassava wastewater can be used if associated with other sources of nutrients.

Key words: *Zea mays* L., agricultural use of waste, eco-sanitation, yellow waters

Teores de nutrientes e crescimento de milho fertigado com urina humana e manipueira

RESUMO: Este trabalho objetivou avaliar os teores dos macronutrientes (NPK e S) e o crescimento do milho 'Potiguar' fertigado com urina humana, manipueira e suas associações com NPK. O experimento foi instalado em casa de vegetação localizada no Campus I da Universidade Federal de Campina Grande. Utilizou-se delineamento experimental inteiramente casualizado, composto por oito tratamentos, correspondentes a fertigação com fertilizante mineral na fórmula de NPK; orgânica composta por urina humana, manipueira e água amarela associada à manipueira; organonomineral composta por urina humana adicionada de fósforo e potássio, manipueira mais nitrogênio e fósforo e urina humana associada à manipueira mais fósforo, com cinco repetições. Aos 50 dias após a semeadura (DAS) foram avaliados os teores foliares de NPK e S e as variáveis de crescimento: número de folhas, altura de planta, diâmetro caulinar, área foliar, massa fresca e seca das folhas, massa do caule e da parte aérea. Os teores de N e P, e as variáveis de crescimento: número de folhas, altura de planta, massa fresca e seca das folhas, massa do caule e da parte aérea foram influenciados pela fertigação com urina humana, manipueira e suas associações com NPK. Nas folhas do milho 'Potiguar' os teores acumulados de N, P, K e S, aos 50 DAS, variaram na sequência N > K > P > S. A urina humana tem potencial como fonte de N na fertigação do milho e a manipueira pode ser utilizada se associada a outras fontes de nutrientes.

Palavras-chave: *Zea mays* L., uso agrícola de resíduos, ecossaneamento, águas amarelas

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Introduction

The use of alternative sources of fertilizers arises as an alternative to minimize costs with the acquisition of synthetic fertilizers and the environmental impacts resulting from the exploitation of natural resources. In this context, special attention has been given to the agricultural use of organic wastes from sanitation (wastewater and sludge produced in their treatment systems, manure from livestock farming and biodegradable municipal solid waste).

Among the wastewaters with potential for agricultural use, human urine as domestic effluent and cassava wastewater as an agroindustrial effluent from cassava root processing stand out. Human urine has low concentrations of pathogens, containing considerable amounts of nutrients (nitrogen, phosphorus, potassium, calcium, sulfur and magnesium) that are important for fertilization of plants which have been used in agriculture since ancient times (Karak & Bhattacharyya, 2011; Ranasinghe et al., 2016). According to Conceição et al. (2013), cassava wastewater stands out for the high concentrations of nitrogen, phosphorus, potassium, calcium, magnesium, copper, zinc and manganese; potassium being the macronutrient at highest concentration compared to the others can be used as a potential fertilizer.

The agricultural use of human urine associated with cassava wastewater has been tested in the cultivation of cowpea (Araújo et al., 2017a), lettuce (Araújo et al., 2017b) and bell pepper (Ramos et al., 2017). According to Araújo et al. (2017a, b), the highest growth of cowpea and production of lettuce were obtained with fertigation with human urine associated with cassava wastewater. On the other hand, Ramos et al. (2017) obtained increase in the quality of bell pepper fruits under fertigation with only cassava wastewater.

In this context, it is extremely relevant to conduct research aiming to analyze the influence of fertigation with human urine associated with cassava wastewater on the nutritional state of corn. Therefore, this study aimed to evaluate the concentrations of nitrogen, phosphorus, potassium and sulfur and the growth of 'Potiguar' corn (*Zea mays* L.) fertigated with human urine and cassava wastewater as sources of macronutrients and with these effluents associated with mineral fertilizers.

Material and Methods

The study was carried out between November 2015 and January 2016, under greenhouse conditions, at the Centro de Tecnologia e Recursos Naturais (CTRN) of the Universidade Federal de Campina Grande (UFCG), in the city of Campina Grande, PB, Brazil (7° 13' 50" S, 35° 52' 52" W, and 551 m of altitude).

The experimental design was completely randomized, with eight treatments and five repetitions, totaling 40 experimental plots. Treatments consisted of a control, without fertilizer application (1 - NF); fertigation with NPK (2 - NPK); only human urine (3 - U); only cassava wastewater (4 - W); human urine + cassava wastewater (5 - U + W); human urine + PK (6 - U + PK); cassava wastewater + NP (7 – W + NP); and human urine + cassava wastewater + P (8 - U + W + P). Human urine was used as a source of N and cassava wastewater as source of K, in order to supply the primary macronutrients through single and combined application of the wastewaters, as well as mineral fertilizers, aiming to achieve the NPK requirements in all treatments. The mineral fertilizers were urea (45.9% N), single superphosphate (18.9% P_2O_5) and potassium chloride (60% K_2O).

Corn was grown in plastic pots adapted as drainage lysimeters with 30 L capacity, installed at spacing of 1.0 m between rows and 0.50 m in the row. Each pot was perforated at the bottom for the introduction of a drain, that is, a tube with 15 cm length and 6 mm nominal diameter, which was connected to a 2.0 L plastic bottle to collect the drainage effluent, allowing its recirculation and aiming to avoid possible losses of leached nutrients through the drainage water due to irrigation.

In the filling process, the pots received a 1.0 kg layer of crushed stone (nº 0), which covered the base, and another 34.0 kg layer of a sandy loam Psamments, properly pounded to break up clods, sieved and not limed, from the rural area of the municipality of Esperança, PB, Brazil, with the following characteristics: pH (H_2O) = 5.58; EC (saturation extract) = 0.56 mmhos cm^{-1}; Al = 0 $cmol_c$ dm^{-3}; Mg = 2.78 $cmol_c$ dm^{-3}; Ca = 9.07 $cmol_c$ dm^{-3}; K = 0.33 $cmol_c$ dm^{-3}; Na = 1.64 $cmol_c$ dm^{-3}; P = 3.98 mg dm^{-3}; SB = 13.72 $cmol_c$ dm^{-3}; OC = 1.70%; OM = 2.93% and d = 1.28 g cm^{-3}.

After filling the pots with the soil, the soil moisture content was raised to field capacity. Subsequently, sowing was carried out with six seeds of corn, cultivar 'Potiguar', equidistantly distributed in each pot. At 15 days after sowing (DAS), thinning was performed, leaving two plants per pot.

The corn 'Potiguar' used in this study, is a genetic material with early cycle, medium size, kernels well protected by the husks, and ears with commercial standard for fresh consumption. This cultivar has been adapted to the Northeast region of Brazil (EMPARN, 2017).

Water replacement depths were estimated for each experimental plot with irrigation interval of 2 days based on the water balance (difference between the average volume applied and the volume drained, sufficient to maintain the soil at field capacity). The water used in irrigation was from the public supply network of the city of Campina Grande, PB, Brazil.

Human urine was collected in three single-family residences in the city of Campina Grande, PB, Brazil, and the contributors were males aged 18 to 55 years, non-smokers, who had not made continuous use of any type of medication, in order to avoid indirect application of xenobiotics in the crop. After collection, the undiluted human urine was subjected to treatment, through the technique of storage in 20 L plastic bucket maintained hermetically closed at room temperature for 60 days before being used (Richert et al., 2010). This treatment is necessary to increase pH and consequently inactivate possible pathogenic microorganisms that may be present in the urine.

Cassava wastewater was collected in a flour mill, located in the District of Jenipapo, municipality of Puxinanã, PB, Brazil, and also underwent treatment, which consisted of a process of anaerobic digestion for a 90-day period. This treatment process was carried out in a 85 L plastic container, which was kept closed, with an empty space of 10 cm inside. The lid of the plastic container was connected to a tube with the other end attached to a 2 L bottle full of water at 0.10 m height, in order to facilitate the release of gases generated during the process and prevent the entry of free oxygen.

After treatment, the wastewater and urine were analyzed according to the methodology recommended by the Standard Methods for Wastewater (APHA, 2005) and their attributes are presented in Table 1.

Fertigation began at 15 DAS, in which each plot received equivalent to 100 mg of N kg^{-1} of soil, 300 mg of P kg^{-1} of soil and 150 mg of K kg^{-1} of soil, according to the recommendation of Novais et al. (1991).

The quantities of human urine and cassava wastewater applied in each plot were estimated based on the dose recommended by Novais et al. (1991) (100 mg of N kg^{-1} of soil and 150 mg of K kg^{-1} of soil) considering the concentrations of N and K in the effluents (Table 1).

Fertigation with mineral fertilizers was split into four portions and applied at 15, 22, 29 and 37 DAS. In treatments containing human urine and/or cassava wastewater (Treatments 3, 4, 5, 6, 7 and 8), fertigation was split into 12 portions and applied at 15, 17, 19, 21, 23, 25, 27, 29, 31, 33, 35 and 37 DAS. This more prolonged splitting for treatments containing human urine and cassava wastewater was necessary to promote greater dilution of the volumes applied in each fertigation event, avoiding possible negative effects that could hamper plant development.

The following growth components were evaluated at 50 DAS: number of leaves (NL), plant height (PH, cm), stem diameter (SD, mm), leaf area (LA, cm^2), fresh mass of leaves and of stem (LFM and StFM, g), dry mass of leaves and of stem (LDM and StDM, g), and shoot fresh mass and shoot dry mass (ShFM and ShDM, g $plant^{-1}$).

The number of leaves was determined by counting the leaves in the plant, from the basal leaves to the last open leaf. Plant height (PH, cm) was determined using a graduated tape in centimeters considering the distance from the plant collar to the insertion of the flag leaf. Stem diameter (SD, mm) was measured with a digital caliper at the first internode on the stem. Leaf area (LA, cm^2) was estimated according to the method proposed by Francis et al. (1969), which consists of the product of the greatest width (B) by the average length (L) of corn leaves, multiplied by 0.75 (L x B x 0.75).

For the determination of fresh mass (g $plant^{-1}$), one plant of each repetition was cut close to the soil, divided into stem and leaves, and weighed on a digital scale with precision of 0.01 g. Subsequently, the leaves and stem were placed in previously identified paper bags and taken to an oven with forced air circulation and controlled temperature of 65 °C for 72 h, to determine the dry mass (g $plant^{-1}$).

After weighing, the dry leaves of corn plants were ground in Wiley-type mill to determine the concentrations of nitrogen (N, g kg^{-1}), phosphorus (P, g kg^{-1}), potassium (K, g kg^{-1}) and sulfur (S, mg kg^{-1}). These determinations were performed through chemical analyses, according to the methodology described by EMBRAPA (2009).

After checking the homogeneity of variances, the obtained data were subjected to analysis of variance by F test at $p \leq 0.05$ and $p \leq 0.01$ and to mean comparison test (Tukey) in the software Assistat v. 7.7 Beta (Silva & Azevedo, 2016).

Results and Discussion

According to the summary of the analysis of variance for the concentrations of nitrogen, phosphorus and potassium (Table 2), there was significant ($p \leq 0.01$) effect of treatments on N and P concentrations, indicating that the fertigation had influence on these variables. By contrast, K concentrations were not influenced ($p > 0.05$) by the treatments tested.

As for the mean leaf N concentrations, the treatments 1 (without fertilizer application) and 4 (fertigation with cassava wastewater) differed significantly from the others (2,

Table 2. Summary of analysis of variance, reference range and means for leaf concentrations of N, P and K of corn 'Potiguar' fertigated with human urine, cassava wastewater and mineral fertilizers, at 50 days after sowing

SV	DF	Mean square		
		N	P	K
Treatments	7	161.54833**	4.38242**	16.7396ns
Residual	32	2.77667	0.30428	6.6099
CV (%)	-	6.48	18.59	10.97
Considered adequate[1]		g kg^{-1}		
		27-35	2.0-4.0	17-35
Treatments		Means (g kg^{-1})		
1 - NF		12.13 b	1.33 c	19.34 a
2 - (NPK)		30.33 a	3.39 ab	23.80 a
3 - (U)		29.87 a	2.36 bc	21.59 a
4 - (W)		15.87 b	1.74 c	22.10 a
5 - (U + W)		29.87 a	2.23 bc	26.37 a
6 - (U + PK)		29.87 a	3.94 a	23.55 a
7 - (W + NP)		28.00 a	4.45 a	26.08 a
8 - (U +W+ P)		29.87 a	4.31 a	24.60 a

[1]Ranges of leaf nutrient concentrations considered adequate for corn (Malavolta et al., 1997; EMBRAPA, 2009); SV – Source of variation; DF – Degrees of freedom; CV – Coefficient of variation; NF – No fertigation; NPK – Nitrogen, phosphorus and potassium; U – Human urine; W – Cassava wastewater; U + W – Urine + cassava wastewater; U + PK – Urine + phosphorus and potassium; W + NP – Cassava wastewater + nitrogen and phosphorus; U + W + P – Human urine + cassava wastewater + phosphorus; ns, **, * - Not significant, significant at $p \leq 0.01$ and $p \leq 0.05$ by F test; Means followed by the same letter, in the column, do not differ by Tukey test ($p \leq 0.05$)

Table 1. Physicochemical characterization of the human urine and cassava wastewater used in the experiment

Effluent	Attributes								
	NTK	N-NH_3	NO_3	P-PO_4^{-3}	K	Na	Ca+Mg	pH	EC
	(g L^{-1})								(dS m^{-1})
U	6.668	5.257	0.002	0.325	1.558	2.509	0.034	9.12	42.70
W	1.199	0.336	0.019	0.338	4.004	0.096	2.800	3.75	11.75

U - Human urine; W - Cassava wastewater; TKN - Total Kjeldahl nitrogen; NH_3-N - Ammoniacal nitrogen; NO_3 - Nitrate; P–PO_4^{-3} - Soluble orthophosphate; K - Potassium; Na - Sodium; Ca+Mg - Total hardness; pH - Hydrogen potential; EC - Electrical conductivity

3, 5, 6, 7 and 8) (Table 2). On the other hand, the lowest N concentrations were 12.13 g kg^{-1}, obtained when corn plants did not receive fertilizer (1 – NF), and 15.87 g kg^{-1}, obtained under fertigation with cassava wastewater (4 – W), and the maximum value was 30.33 g kg^{-1}, obtained under fertigation with NPK. However, it did not differ statistically from the means of treatments 3 (U), 5 (U + W), 6 (U + PK), 7 (W + NP) and 8 (U + W + P). This value was higher than that found by Malafaia et al. (2016), who evaluated the effects of using tannery sludge vermicompost and fertigation with domestic wastewater in the fertilization of corn, cultivar LG 6036, and obtained maximum leaf N concentrations of 3.26 g kg^{-1}. Farinelli & Lemos (2012), studying the effects of topdressing N fertilization on the triple hybrid corn cultivar DKB 466, obtained a mean N concentration of 28.33 g kg^{-1} under fertilization with 120 kg ha^{-1} of urea. Prior et al. (2015), studying the effects of the association between swine wastewater and mineral fertilization on the corn crop and on the soil, obtained leaf N concentration of 22.66 g kg^{-1} under fertigation with 450 m^3 ha^{-1} of wastewater.

For leaf concentrations of P, the means comparison test (Table 2) showed plants not fertilized (1 - NF) and plants fertigated with cassava wastewater (4 - W) differed significantly from those of the other treatments (2 - NPK, 6 - U + PK, 7 - W + NP and 8 - M+U+P).

The maximum P concentrations determined in corn leaves was 4.45 g kg^{-1}, obtained in plants fertigated with cassava wastewater associated with mineral N and P (7 - W + NP), with no statistical difference between plants fertigated with urine associated with mineral fertilizers (6 – U + PK), cassava wastewater associated with mineral fertilizers (7 - W + NP) and urine and cassava wastewater associated with mineral P (8 – U + W + P) and mineral fertilizer (2 - NPK). These P concentrations corroborate those reported by Barreto et al. (2014), who studied the development and accumulation of macronutrients in corn plants fertilized with 44.8 m^3 ha^{-1} of cassava wastewater and obtained 3.56 g kg^{-1} of P.

Based on the mean values (Table 2), it can be seen that, except for the control (1 - NF) and fertigation with only cassava wastewater (4 - W), the other treatments (2 - NPK, 3 - U, 5 - U + W, 6 - U + PK, 7 - W + NP and 8 - U + W + P) met the requirements of N and P of the corn crop, since their means were within the range considered adequate for corn (Malavolta et al., 1997; EMBRAPA, 2009), demonstrating that the N and P present in the human urine and mineral fertilizers used in the fertigation were adequately absorbed by the plants.

With the exception of fertigation with cassava wastewater and the treatment without fertilizer application, the other treatments led to P concentrations inside of the range considered adequate (Malavolta et al., 1997; EMBRAPA, 2009), indicating a positive effect of the fertigation with human urine (3 - U), cassava wastewater associated with urine (5 – U + W), NPK (2 - NPK) and these mineral fertilizers associated with the effluents used (U + PK, W + NP and U + W + P), except treatments (7 – W + NP) and (8 - U + W + P) that exceeded the adequate values.

Although the statistical analysis did not show significant effect of treatments on K concentrations (Table 2), it can be observed that, for all treatments, the leaf K concentrations are within the range considered adequate (17 to 35 g kg^{-1}) for the development of the crop. The maximum value of leaf K concentrations was 26.37 g kg^{-1}, obtained under fertigation with urine associated with cassava wastewater (5 - U + W).

According to the concentrations of K (Table 2), it is observed that all treatments characterized by fertigation had K concentrations higher than those of the control treatment (1 - NF), demonstrating that the nutrients present in the nutrient sources used in fertigation (human urine, cassava wastewater and NPK) were absorbed by the plants.

A probable explanation for the low leaf concentrations of the nutrients analyzed in corn seedlings without fertilization (1 - NF) is related to the nutrient deficiency, which was not overcome during the experiment, because the control treatment (1 - NF) was intended to indicate whether the plants would use the nutrients applied in the other treatments. This hypothesis was confirmed, since the leaf concentrations of N and P analyzed in corn plants subjected to fertigation with treatments containing nutrients (NPK, human urine and cassava wastewater) had higher values than the control treatment.

The low leaf concentrations of N and P obtained in corn leaves subjected to fertigation with only cassava wastewater (4 – W) may be related to the acidity and N deficiency of cassava wastewater because, according to the data from Table 1, the effluent showed pH of 3.75 (acid) and total Kjeldahl N concentration of 1.199 g L^{-1}, i.e., approximately 5.50 g L^{-1} lower than the value in human urine.

According to the summary of the analysis of variance (Table 3) for the number of leaves (NL), plant height (PH), stem diameter (SD) and leaf area (LA) of corn plants, there was a significant effect ($p \leq 0.01$) of treatments on the variables NL and PH.

With respect to the means of NL, plants not fertilized (1 - NF) differed significantly from those of the other treatments

Table 3. Summary of the analysis of variance and means for the number of leaves (NL), plant height (PH), stem diameter (SD) and leaf area (LA) of corn fertigated with human urine and cassava wastewater, at 50 days after sowing

SV	DF	Mean square			
		NL	PH	SD	LA
Treatments	7	2.9598**	1487.0669**	2.4327ns	4408.4588ns
Residual	32	0.6354	86.6771	2.1740	2266.9495
CV (%)	-	5.51	5.66	7.65	10.46
Treatments		**Means**			
		(leaves plant^{-1})	(cm)	(mm)	(cm^2 plant^{-1})
1 - NF		12.50 b	129.75 b	17.86 a	411.41 a
2 - (NPK)		14.75 a	169.00 a	18.61 a	423.14 a
3 - (U)		14.50 a	176.00 a	20.03 a	495.91 a
4 - (W)		14.25 ab	138.50 b	18.74 a	419.41 a
5 - (U + W)		15.25 a	171.25 a	20.06 a	467.74 a
6 - (U + PK)		14.50 a	171.25 a	19.68 a	473.03 a
7 - (W + NP)		15.00 a	182.00 a	19.58 a	491.60 a
8 – (U +W+ P)		15.00 a	177.50 a	19.56 a	460.78 a

SV - Source of variation; DF - Degrees of freedom; CV - Coefficient of variation; NF - No fertigation; NPK - Nitrogen, phosphorus and potassium; U - Human urine; W - Cassava wastewater; U + W - Urine + cassava wastewater; U + PK – Urine + phosphorus and potassium; W + NP - Cassava wastewater + nitrogen and phosphorus; U + W + P – Human urine + cassava wastewater + phosphorus; ns, **, * - Not significant, significant at $p \leq 0.01$ and $p \leq 0.05$ by F test; Means followed by the same letter, in the column, do not differ at $p \leq 0.05$ by Tukey test except 4-W which did not differ from another treatments. The minimum and maximum means of NL were 12.50 and 15.25 leaves plant^{-1}, obtained in treatments without fertilization (1 - NF) and under fertigation with urine associated with cassava wastewater (5 - U + W), respectively.

For plant height (PH), there was significant difference between plants under treatments 2, 3, 5, 6, 7 and 8, and plants that were not fertilized (1 - NF) and fertigated with cassava wastewater (4 - W). The minimum means were 129.75 and 138.50 cm, were obtained in treatment without fertilization (1 - NF) and under fertigation with cassava wastewater (4 - W), respectively. The maximum values were 177.50 and 182.00 cm, obtained under fertigation with human urine associated with cassava wastewater and mineral P (8 - U + W + P) and with cassava wastewater associated with mineral NP (7 – W + NP), respectively.

These results corroborate the data reported by Costa et al. (2014), who evaluated plant height and number of leaves in corn, 'Cruzeta', fertigated along the experiment with treated domestic sewage and obtained significant response and maximum means with the application of 100% of wastewater. Costa et al. (2009) evaluated plant height in corn, cultivar BR-106, fertigated with wastewater along the experiment and also obtained significant responses, with mean value higher than the one found in the treatment with no fertigation.

The maximum means of stem diameter and leaf area were 20.06 mm and 495.91 cm^2 plant^{-1}, obtained under fertigation with human urine associated with cassava wastewater (5 - U + W) and human urine (3 - U), respectively.

Table 4 presents the results of the analysis of variance and means of leaf fresh mass (LFM), stem fresh mass (StFM), shoot fresh mass (ShFM), leaf dry mass (LDM), stem dry mass (StDM) and shoot dry mass (ShDM) of 'Potiguar' corn as a function of the treatments. According to the analysis of variance, there was a significant effect ($p \leq 0.01$) on all variables studied.

The means showed statistical difference between the treatments tested. The maximum values for LFM, StFM and ShFM were 207.24, 443.67 and 652.74 g, respectively, obtained under fertigation with human urine associated with mineral fertilizers (PK) (6 – U + PK). For the variables LDM, StDM and ShDM, the maximum means of 41.61, 52.82 and 90.58 g were obtained under fertigation with human urine associated with cassava wastewater and mineral P (8 – U + W + P), human urine (3 - U) and human urine associated with cassava wastewater (5 – U + W), respectively.

According to the data shown in Table 4, fertigation with only cassava wastewater (4 – W) in comparison to other treatments caused reductions in the variables LFM, LDM, StDM, ShFM and ShDM. Compared to the control (1 – NF), the biomass losses were equal to 27.26, 4.93, 1.33, 20.66 and 6.39 g, respectively, suggesting that the nutrients present in the cassava wastewater, applied via fertigation, were not assimilated by the plants. This was confirmed by leaf analysis results, which showed N and P concentrations below the range considered adequate for the corn crop (Table 2).

These effects may be related to the low pH (3.75) and N concentration (1.199 g L^{-1}) present in the cassava wastewater (Table 1) supplied via fertigation through treatment 4 (fertigation with cassava wastewater), because it applied an amount of cassava wastewater equivalent to 150 mg of K kg^{-1} of soil, according to the recommendation of Novais et al. (1991). This hypothesis was confirmed because, when corn plants were fertigated with cassava wastewater associated with human urine (treatments 5 - U + W and 8 - U + W + P) or urea associated with P (7 - W + NP), the variables NL, PH, SD, LA (Table 3) and LFM, LDM, StFM, StDM, ShFM and ShDM (Table 4) were superior to the values found in the control (1 - NF) and in the treatment of fertigation with cassava wastewater (4 - W). These results corroborates with the result obtained by Barreto et al. (2014), who investigated the growth and nutrient accumulation of corn plants cultivated in two soils with different textures and subjected to increasing doses of cassava wastewater. These authors observed increasing linear effect on shoot fresh mass and shoot dry mass and leaf N concentrations as a function of the cassava wastewater doses and maximum means at the maximum dose of cassava wastewater, suggesting that the nutrients present in the cassava wastewater were well used by plants.

Table 4. Summary of the analysis of variance and means for leaf fresh mass (LFM), stem fresh mass (StFM), shoot fresh mass (ShFM), leaf dry mass (LDM), stem dry mass (StDM) and shoot dry mass (ShDM) of 'Potiguar' corn fertigated with human urine and cassava wastewater

SV	DF	Mean square					
		LFM	StFM	LDM	StDM	ShFM	ShDM
Treatments	7	6252.5314**	27793.6008**	191.1182**	321.4263**	55386.1862**	883.4954**
Residual	32	640.2353	1188.7939	10.5078	26.8629	1767.8717	43.3226
CV%	-	15.82	9.29	9.38	11.18	7.99	8.25
Treatments		Means (g plant^{-1})					
1 - NF		118.17 cd	237.03 b	26.67 b	32.69 b	351.63 b	59.22 b
2 - (NPK)		147.83 bcd	411.95 a	34.63 a	52.81 a	559.78 a	86.47 a
3 - (U)		157.83 abc	434.03 a	35.04 a	52.82 a	585.53 a	86.91 a
4 - (W)		90.91 d	240.28 b	21.74 b	31.36 b	330.97 b	52.83 b
5 - (U + W)		181.04 ab	398.63 a	39.29 a	51.57 a	575.18 a	90.58 a
6 - (U + PK)		207.24 a	443.67 a	38.28 a	50.85 a	652.74 a	87.73 a
7 - (W + NP)		185.49 ab	404.26 a	39.21 a	48.47 a	581.31 a	85.57 a
8 - (U+W + P)		190.70 ab	399.34 a	41.61 a	50.29 a	573.54 a	89.18 a

SV - Source of variation; DF - Degrees of freedom; CV - Coefficient of variation; NF - No fertigation; NPK - Nitrogen, phosphorus and potassium; U - Human urine; W - Cassava wastewater; U + W - Urine + cassava wastewater; U + PK - Urine + phosphorus and potassium; W + NP - Cassava wastewater + nitrogen and phosphorus; U + W + P - Human urine + cassava wastewater + phosphorus; **,* - Significant at $p \leq 0.01$ and $p \leq 0.05$ by F test; Means followed by the same letter, in the column, do not differ at $p \leq 0.05$ by Tukey test

Conclusions

1. Human urine showed potential to be used as nitrogen source in corn fertigation.

2. Cassava wastewater can be used in corn fertigation if associated with other sources of nutrients.

3. Human urine associated with cassava wastewater and applied via fertigation is an alternative to minimize the use of mineral fertilizers required in corn fertilization and recycle nutrients that are usually wasted.

4. Maximum leaf N concentrations were obtained in treatments of fertigation with NPK, human urine, human urine associated with cassava wastewater and their association with mineral fertilizers.

5. Maximum leaf P concentrations were obtained in treatments of fertigation with human urine associated with PK, cassava wastewater associated with NP and human urine associated with cassava wastewater and P.

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