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The use of "manipueira" wastewater derived from cassava processing as organic fertilizer in sunflower cultivation

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Abstract

The use of manipueria (the organic wastewater from the cassava flour manufacturing process) is a promising management strategy in agriculture because it is a rich nutrient source for plants. Thus, this study aimed at evaluating the use of manipueria as a fertilizer for sunflower cultivation. The field experiment was carried out in a randomized complete block design with 6 treatments (doses of cassava: 0, 8.5, 17, 34, 68 and 136 m^3 ha^{-1}) and four replications, using the sunflower cultivar Helio 250. The experiment was collected at 90 days after sowing. We evaluated the shoot fresh and dry mass, achenes and oil yield, nitrogen, phosphorus and potassium content in leaves, stem, chapter and achenes. Data were initially submitted to analysis of variance at 5% significance level and then to regression analysis. The manipueira wastewater application significant increased fresh and dry mass accumulations in shoot, content of nutrients such as nitrogen, phosphorus and potassium in plant, as well grain and oil yields. The dose of 136 m^3 ha^{-1} resulted in the highest fresh and dry mass production in shoot and greater macronutrient accumulation supplying enough nitrogen, phosphorus and potassium to the plant, confirming the potential as an organic fertilizer. The 4562.52 and 1965.19 kg ha^{-1} in achene and oil, respectively, obtained with the use of manipueira wastewater,yields are above the sunflower national and international average production.

Keywords. *Helianthus annuus* L., *Manihot esculenta* Crantz, liquid waste, waste management in agriculture.

Introduction

As population growth and progress in the production systems increase, the extensive consumption of the inputs will obviously generate huge amounts of waste, aggravating environmental problems on a global scale. Agriculture and agro-industries generate copious amounts of lethal waste which when incorrectly disposed, severely damages the environment and all life forms (Freire et al., 2000; Oliveira and Jucá, 2004; Costa et al., 2009). Currently, the escalating waste production is negatively impacting the environment because it is being created at a much faster rate than it is being degraded (Fiori et al., 2008). Therefore, a wise alternative would be to utilize the waste to fertilize crops, in a bid to minimize reliance on chemical fertilizers, which need to be extracted from rocks or require oil for their production, both of which have a protracted geologic cycle (Bonfim-Silva et al., 2011). Cassava (*Manihot esculentum* Crantz) ranks among the most popular and inexpensive food staples in several countries, including Brazil (Osundahunsi, Seidu and Mueller, 2011). The global cassava production in 2013 stood at 276,721,584 million tonnes, a productivity of 13,347.4 kg ha^{-1}. Brazil is the world's third largest producer of cassava, totaling 23 million tons, which is a yield of 13,611.8 kg ha^{-1} (FAO, 2016). Of the solid and liquid wastes resulting from processing the cassava, the liquid residue is proven to most severely damage the environment because of the heavy organic load releasing linamarin, a highly toxic cyanogenic glycoside (Campos et al., 2006). This therefore, necessitates an effective method of minimizing the organic load. However, cassava is rich nutrients, particularly nitrogen, phosphorus, potassium and magnesium, which may render it useful as a fertilizer in agriculture (Cardoso et al., 2009). From this perspective, the waste which would otherwise be dumped and negatively affect the environment, can find use as a nutrient source in the community, assisting small farmers, and enriching the local production. In Brazil, cassava is primarily used as alternative source of fertilizer for crops, animal feed, as well as a control measure of plant diseases and pests (Gonzaga et al., 2008; Dantas et al., 2015; Santos Filho et al., 2015). This concept of profitably utilizing waste has grabbed considerable attention as a method of minimizing the negative environmental impacts caused by the disposal of waste. Sunflower (*Helianthus annuus* L.) is prominent as being among the four main oil producing annual crops globally, and the significance of its cultivation has meteorically soared in the international agricultural stage. It is cultivated chiefly for the production of edible oil for human consumption and for the manufacture of biofuels. The Ukraine ranks first in the world, producing 11 million tons of sunflower and an average yield of 2170 kg ha^{-1} (FAO, 2016), while Brazil continues to produce a less significant amount, recording only 109,000 tons and an average yield of 1581.3 kg ha^{-1} for grain yield and 563.80 kg ha^{-1} for oil.

Therefore, the use of manipueira wastewater as fertilizer in sunflower cultivation can be a strategy of beneficial management and recovery of the residue, with efficiency in the crop production system, with nutrient supply and possible increase of yield of the productive components. In light of these facts, the objective of the present study was to assess the effect of utilizing manipueira wastewater of cassava as a fertilizer in sunflower cultivation.

Results and discussion

Fesh weight and dry weight of shoot

When manipueria was applied as a fertilizer it induced a linear increase in the fresh weight of the shoot (FWS) (Fig. 1A) and dry weight of shoot (DWS) (Fig. 1B) of the sunflower plants. The fresh weights of 381.16 g $plant^{-1}$ and 1300.03 g $plant^{-1}$ were obtained for the manipueira doses of 0 and 136 m^3 ha^{-1}, respectively, recording an increase of 241.07%. The dry mass of shoot registered an increase of 245.7% of the dry weight in response to the highest manipueira dose compared with the treatment without such an application.

Nitrogen accumulation

This positive effect of manipueria on the sunflower culture induced this dramatic increase because of the high concentrations of organic load and mineral nutrients present in the cassava residue (Table 2). Such sharp increases in the fresh mass and dry mass of the shoot in different cultures have been credited to the application of organic fertilizers, as noted by Barreto et al. (2014). They calculated the initial growth of the fertilized maize with specific doses of cassava in two soils (sandy loam and clay loam) and reported significant increases of 26% on average, in the fresh weight of the corn plant shoots.

A linear increase was observed in the accumulation of nitrogen, phosphorus and potassium in the leaves, stem, chapter and achenes of the sunflower plants in response to the manipueira doses applied, demonstrating the promise and potential that cassava offers as a fertilizer (Fig. 2).

In the absence of manipueira application the nitrogen accumulation (dose 0 m^3 ha^{-1}) in the leaves was reportedly 0.248 g $plant^{-1}$, whereas in response to the highest dose of manipueira (136 m^3 ha^{-1}) it rose to 1.349 g $plant^{-1}$, indicating a 442% increase. These results concur with the reports of Fia et al. (2006) who evaluated the productivity and nutrient concentrations in maize. They used increasing doses of sewage sludge containing 4.746 mg kg^{-1} of nitrogen and recorded increased nitrogen concentrations with the application of increased dosages of the residue.

With respect to the nitrogen accumulation in the sunflower stem, the maximum and minimum values determined by regression equations were 0.075 and 0.362 g $plant^{-1}$, when equal doses of manipueira 0 and 136 m^3 ha^{-1}, respectively, were used. Nitrogen accumulation in the chapters exhibited trends identical to the stem, showing an accumulation of 0.799 g $plant^{-1}$ for a manipueira dose of 0 m^3 ha^{-1} and an increase to 4.073 g $plant^{-1}$ in response to a dose of 136 m^3 ha^{-1}, recording a 410 % increment. The nitrogen accumulation in achenes was 1.425 g $plant^{-1}$ at a manipueira dose of 0 m^3 ha^{-1} which rose to 2,844 g $plant^{-1}$ in response to the dose of 136 m^3 ha^{-1}, recording a 100% increase. Wolf et al. (2013) reported similar results in which a linear increase in the concentration of nitrogen in the sunflower achenes was observed, due to the increased amounts of nitrogen applied.

When the whole plant was considered, the greatest nitrogen accumulation in response to each dose and the sum of the leaves, stem, chapter and achenes, was 2.547; 2.926; 3.06; 4.066; 5.585 and 8.624 g $plant^{-1}$, for manipueira doses of 0; 8.5; 17; 34; 68 and 136 m^3 ha^{-1} respectively, corresponding to the nitrogen extractions of 127, 146, 165, 203, 279 and 431 kg ha^{-1}. Nitrogen extractions were found to be in the order of each plant organ in sunflower as given: Chapter > achenes > leaf > stem. On comparing the nitrogen extraction values, they were found to exceed those recorded by Zobiole et al. (2010). Maximum nitrogen accumulation with respect to the sum of the leaves, petioles, stems, chapter and achenes was 3.751 g $plant^{-1}$, at 85 days, corresponding to an extraction of 150 kg ha^{-1} of nitrogen. The nitrogen accumulation in the leaves suggest that specific levels were sufficient for the plants because no deficiency symptoms were observed.

Phosphorus accumulation

For phosphorus accumulation in the leaves, stem, chapter and achenes in the sunflower plants a trend similar to that of the nitrogen behavior was observed (Fig.3). The phosphorus accumulation in the leaves was 0.051 and 0.237 g $plant^{-1}$ when the manipueira doses equal to 0 and 136 m^3 ha^{-1} were used, respectively. For the phosphorus accumulation in the stem the same behavior was observed, at 0.0711 and 0.264 g $plant^{-1}$, in response to the manipueira doses of 0 and 136 m^3 ha^{-1}, respectively. With respect to the accumulation of phosphorus in section, in the absence of cassava application (0 m^3 ha^{-1}) 0.289 g $plant^{-1}$ was obtained, while the application of the highest dose (136 m^3 h^{-1}) resulted in the phosphorous accumulation of 1.419 g $plant^{-1}$, an increase of 390.3%. For the phosphorus accumulation in the achenes 0.455 g $plant^{-1}$ was reported for a manipueira dose of m^3 ha^{-1} and 0.958 g $plant^{-1}$ at a dose of 136 m^3 ha^{-1}.

The total phosphorus accumulation, meaning the sum of the leaves, stem, chapter and achenes, were 0.867; 0.990; 1.113; 1.359; 1.851 and 2.878 g $plant^{-1}$ for doses 0; 8.5; 17; 34; 68 and 136 m^3 ha^{-1}, respectively, equivalent to the related phosphorus extraction of 49.5; 55.7; 67.9; 92.5 and 143.9 kg ha^{-1}. These results do not concur with those reported by Zobiole et al. (2010) who recorded a maximum phosphorus accumulation in the plant (leaves, petioles, stems, chapter and achenes) of 0.605 g $plant^{-1}$, equivalent to the extraction of 24 kg ha^{-1} of phosphorus, as mentioned below the results of this research. Phosphorus extraction in the order of the plant organs was: chapter > achenes > stem > leaves.

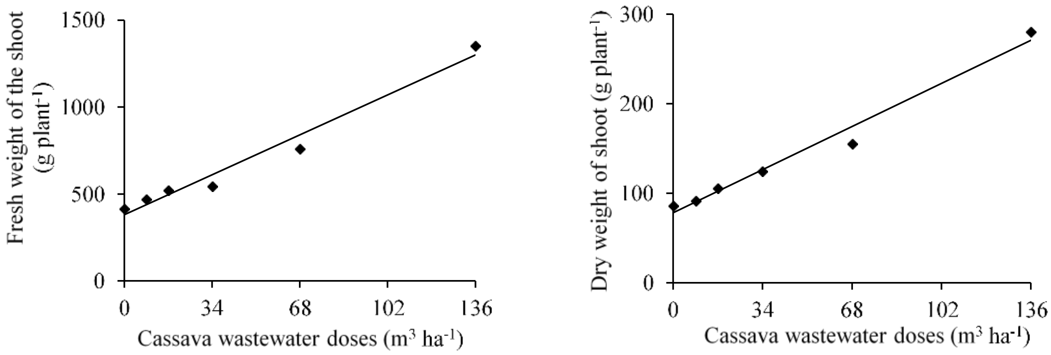
Potassium accumulation

The total accumulation of potassium in the entire sunflower plant showed a linear increase at the levels of 0.087; 0.0124; 0.01 and 0.0025 g $plant^{-1}$, in response to the increase in the manipueira doses applied (Fig. 4). The highest potassium accumulation in the leaves was 1.522 g $plant^{-1}$ for a manipueira dose of 136 m^3 ha^{-1} and the lowest potassium accumulation was 0.334 g $plant^{-1}$ in the absence of manipueira application (dose 0 m^3 ha^{-1}). With respect to the potassium accumulation in the stem, the estimated average values of 0.567 and 2.253 g $plant^{-1}$ were obtained when equal manipueira doses of 0 and 136 m^3 ha^{-1}, respectively, were used enabling an extraction of 28.4 and 112.6 kg ha^{-1} potassium, which was a 297% increase. Similar to the potassium buildup in the chapter, the lowest value of 1,189 g $plant^{-1}$ was reported in the absence of cassava application (0

Table 1. Physical and chemical characteristics of the soil before applying *manipueira.*

Sand	Silt	Clay	pH	EC*	P	K^+	Ca^{2+}	Mg^{2+}	Na^+	Al^{3+}	$H^+ + Al^{3+}$	OC*
-----------g kg^{-1}---------			(1:2,5 H_2O)	dS m^{-1}	mg dm^{-3}	----------------------cmol$_c$ dm^{-3}---------------------						g kg^{-1}
578	122	300	6.60	0.55	7.47	0.45	2.7	2.8	0.27	0.00	2.93	28

* EC: Electrical Conductivity; Organic carbon



$\hat{Y} = 6.7564^{**} x + 381.16$ $\quad$ $\hat{Y} = 1.4149^{**} x + 78.306$

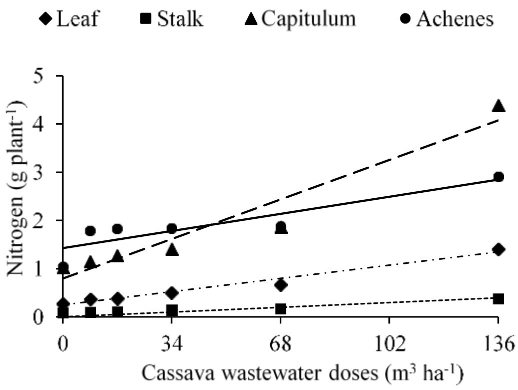
$R^2 = 0.97$ $\quad$ $R^2 = 0.98$

Fig 1. Fresh weight of the shoot (A) and Dry weight of shoot (B) of the sunflower plants based on the manipueira doses. ** Significant at ($p \leq 0.01$).

Table 2. Characterization of physical-chemical parameters of *manipueira.*

COD*	EC*	pH	N	P	K^+	Ca^{2+}	Mg^{2+}	Na^+	$SO4^{2-}$	Cl^-
mg L^{-1}	dS m^{-1}		--mg L^{-1}--							
66.62	7.27	6.60	3064.0	312.0	3200.0	241.9	1588.2	390.0	2205.0	795.0

COD: Biochemical oxygen demand, CE: Electrical Conductivity



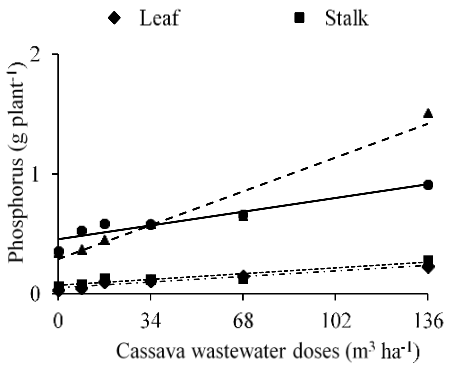
$\hat{Y}\blacklozenge = 0.2482 + 0.0081^{*} x$ $\quad$ $R^2 = 0.97$

$\hat{Y}\blacksquare = 0.0752 + 0.0021^{**} x$ $\quad$ $R^2 = 0.95$

$\hat{Y}\blacktriangle = 0.7986 + 0.0241^{**} x$ $\quad$ $R^2 = 0.93$

$\hat{Y}\bullet = 1.4246 + 0.0104^{**} x$ $\quad$ $R^2 = 0.80$

Fig 2. Nitrogen accumulation in sunflower based on the manipueira doses, significant at ($p > 0.05$), ** significant at ($p \leq 0.01$).



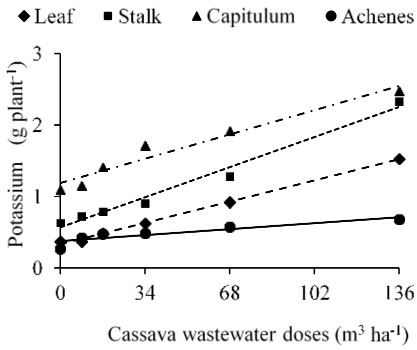
$\hat{Y}\blacklozenge = 0.0513 + 0.0014^{**}x$ $R^2 = 0.95$

$\hat{Y}\blacksquare = 0.0711 + 0.0014^{**}x$ $R^2 = 0.89$

$\hat{Y}\blacktriangle = 0.2894 + 0.0083^{**}x$ $R^2 = 0.95$

$\hat{Y}\bullet = 0.4554 + 0.0034^{**}x$ $R^2 = 0.89$

Fig 3. Phosphorus accumulation in sunflower plant according to manipueira doses. ** Significant at ($p \leq 0.01$).



$\hat{Y}\blacklozenge = 0.3337 + 0.0087^{**}x$ $R^2 = 0.99$

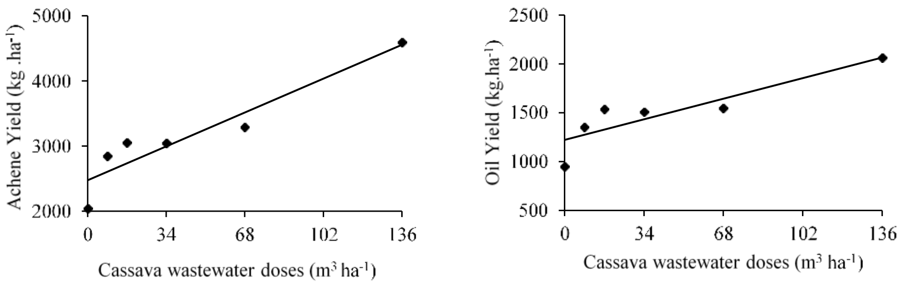
$\hat{Y}\blacksquare = 0.5671 + 0.0124^{**}x$ $R^2 = 0.98$

$\hat{Y}\blacktriangle = 1.1894 + 0.01^{**}x$ $R^2 = 0.95$

$\hat{Y}\bullet = 0.3766 + 0.0025^{**}x$ $R^2 = 0.82$

Fig 4. Potassium accumulation in sunflower based on the manipueira doses. **Significant at ($p \leq 0.01$).

A B



$\hat{Y} = 15.274^{**}x + 2476.3$ $R^2 = 0.88$ $\hat{Y} = 6.211^{**}x + 1220.5$ $R^2 = 0.79$

Fig 5. Achene yield (A) and oil yield (B) in sunflower based on the manipueira doses. ** Significant at ($p \leq 0.01$)

$m^3\ ha^{-1}$), whereas the for the highest dose of cassava (136 $m^3\ ha^{-1}$) a greater accumulation of 2.548 g $plant^{-1}$ was recorded, an increase of about 89.4%. The potassium extraction was reportedly 59.4 and 127.4 kg of potassium ha^{-1}, respectively. In the achenes, the potassium accumulation followed a similar trend with 0.377 g $plant^{-1}$ for the lowest cassava dose and 0.711 g $plant^{-1}$ for the highest dose, showing an extraction value of 18.8 and 35.5 kg ha^{-1} of potassium. On verifying the total accumulation for all the plant organs of the sunflower, we recorded 2.467, 2.752, 3.038, 3.609, 4.751, 7.034 g $plant^{-1}$ for the manipueira doses (0, 8.5, 17, 34, 68 and 136 m^3 ha^{-1}), respectively, with extractions of 123.3; 137.6; 151.9; 180.4; 237.5 and 351.7 kg ha^{-1}. The order of potash with respect to the plant organs were as follows: Chapter > stem > leaf > achenes. Castro et al. (2006) revealed that the sunflower crop has a high potassium (K_2O) requirement, roughly about 171 kg in the shoot (stem, petiole, leaf, chapter and grains) for each ton of grain produced.

According to the reports of Castro and Oliveira (2005) the total amount of nitrogen, phosphorus and potassium extracted from the shoot for a production of 3176 kg of achenes ha^{-1} was 130 kg ha^{-1} of nitrogen, 25 kg phosphorus ha^{-1} and 400 kg ha^{-1} potassium, respectively.

This study shows the amounts of extracted nitrogen, phosphorus and potassium, in light of the shoot production of 4498 kg ha^{-1} from the achenes for the higher dose of cassava (136 m^3 ha^{-1}) were 431, 144 and 341 kg ha^{-1}, respectively.

Achene and oil yield

The yields from the achenes (Fig. 5A) and oil (Fig. 5B) showed a positive response to the increase in the cassava doses applied to the soil, and the estimated maximum yield values from the achenes and oil were recorded at 4562.52 and 1965.19 kg ha^{-1}, respectively. The maximum yield from the achenes and therefore, the greater oil yield, is linked to suitable plant nutrition including mineral and water availability (Aquino et al., 2013, Uchôa et al., 2011). Appropriate sowing time, air temperature, rainfall, solar radiation and planting density (Thomaz et al., 2012) are considered favorable by Castro and Farias (2005), for the oil content in the achenes ranging between 28-60%.

An in-depth study of the agronomic and nutritional characteristics of the sunflower cultivars grown in the field with the application of chemical fertilizers, Aquino et al. (2013) reported the achene yield, for the hybrids Helio 250 and Helio 251, equal to 3950 and 4631 kg ha^{-1}, respectively. The authors reported high crop productivity crediting the increase to the favorable temperature and water availability during growth season of sunflower.

According to Thomaz et al. (2012), the yields of achenes and oil can be determined at different sowing times, they reported that among the sunflower hybrids cultivated under field conditions, the hybrid Helio 250 revealed a yield of 1329 kg ha^{-1} for the achenes, a value less than that reported for the other hybrids like M734, Aguará 4 and Catissol, which averaged 1820, 1805 and 1368 kg ha^{-1}, respectively, in the ten seasons studied.

Materials and Methods

Localization, design of experiments and soil characteristics

The experiment was conducted from October 2012 to January 2013 in the municipality of Vitoria de Santo Antao, Pernambuco State, Brazil, with the geographical coordinates 8º8'0 "S and 35º22'0" W. The average temperatures recorded were a maximum of 33 ° C and minimum of 21 ° C and relative humidity of 77%, during the experimental period. The soil was categorized as yellow Oxisol. Soil sampling was done in the 0 to 0.4 m layer and analyzed to determine its physical and chemical characteristics (Table 1).

The field experimental design selected was randomized blocks with 6 subplots to evaluate 6 doses of manipueira viz., 0; 8.5; 17; 34; 68 and 136 m^3 ha^{-1} with four replications. The manipueira was applied in doses of 0, 25, 50, 100, 200 and 400 kg ha^{-1} of potassium, respectively.

Manipueira wastewater application, drip irrigation and experimental conduction

The dose recommended for application to the soil was estimated according to Ribeiro et al. (1999) based on the potassium content of the residue as this is the element with the highest concentration in cassava. The most suitable dose of manipueira was found to be 8.5 m^3 ha^{-1} because the potassium requirements of the sunflower culture under local conditions corresponded to 25 kg ha^{-1} potassium. The other doses were calculated by multiplying the recommended dose by two, four, eight and sixteen times.

Each plot consisted of four rows, each 6 m long, and with 1.0 m space between the plants of 0.20 m, for a total of 120 plants per plot, showing an equivalent density of 50,000 plants ha^{-1}. Each plot was 10.4 m^2 in area, corresponding to 52 plants in the central two rows.

The physical and chemical composition of cassava (Table 2) was examined using the methodology of APHA (1995). The soil was prepared by plowing, disking and subsequent plowing in rows spaced 1.0 m apart to a depth of 0.30 m. Drip irrigation was performed using flexible tape and 16 mm spaced emitters of 0.2 m with a flow rate of 1.0 L h^{-1}. The slides were assessed based on the evapo-transpiration (ETc) rate of the crop. The evapo-transpiration reference (Eto) was estimated adopting the methodology of Hargreaves-Samani (1985), utilizing the crop coefficients (Kc) recommended for the sunflower crop. For every cycle of plants a 357 mm blade was employed.

Cassava was applied in a single dose, in the furrows roughly 0.08 m deep, two weeks prior to planting to circumvent all the ill effects on the plant due to the toxicity of the hydrocyanic acid present in the residue. The sunflower cultivar Helio 250 was used. Five seeds were sown per hole, and seven days post emergence the plants were thinned, to finally have only one plant per hole.

Traits measured

At 90 days post sowing (DAS) when the sunflower chapters were all face down in the developmental stage R9, they were evaluated. The achene yield, oil yield and fresh and dry weight of the shoot, as well as concentrations of nitrogen, phosphorus and potassium in the aerial plant parts were calculated.

The plants that fit the criteria were cut close to the ground, and the aerial parts were segregated into leaves, stems, chapters and achenes. To ascertain the dry mass, the plants were placed in a forced circulation air oven at a temperature of around 65 °C to constant weight. The samples were then processed in a Wiley mill, packed in containers and sealed. To determine the phosphorus and potassium concentrations, digestions were performed utilizing nitro-perchloric and sulfuric acids for the determination of the nitrogen content (Bezerra Neto and Barreto, 2011).

The achene yield was assessed by weighing the achenes of the useful area of the plot. The humidity of the achenes was corrected to 11%, according to the data and the yield was calculated (kg ha^{-1}), taking into account the final stand of the culture of 50,000 plants ha^{-1}. The Soxhlet method was employed to determine the oil content (Bezerra Neto and Barreto, 2011). The oil yield (kg ha^{-1}) was calculated keeping in mind the oil content and achenes (kg ha^{-1}). The fresh weight was measured by weighing 10 plants in the useful area of the plot, and with these data the average of the fresh pasta was estimated (g $plant^{-1}$); the dry weight was assessed after the fresh mass, to achieve a constant mass and based on these data the dry mass was calculated (g plant^{-1}). The accumulations of nitrogen, phosphorus and potassium were assessed by multiplying the concentrations of these macronutrients (g kg^{-1}) by weight of the dry mass (g) for each plant.

Data analysis

Data were submitted to analysis of variance by F test ($p \leq 0.05$). When significant effect was noted, regression analyses were done by selecting significant mathematical models ($p \leq 0.05$), with the highest coefficient of determination.

Conclusion

The utilization of waste in agriculture, as in the case of cassava, is considered a brilliant management strategy and a beneficial recovery of waste, in which the waste becomes a valuable substance that enhances the crop production and completely or partially supplements the nutrient demands of the culture.

The management strategy in agriculture which adopted the utilization of manipueira as a fertilizer for sunflower cultivation recorded satisfactory values for full growth and the nitrogen, phosphorus and potassium contents; besides, the grain and oil yields for the sunflower cultivar Helio 250, reported values much higher than the national and international average.

Manipueira applied in the dosage of 136 m^3 ha^{-1} induced the highest accumulations of the nutrients of nitrogen, phosphorus and potassium, as well as gave good values for the fresh and dry weight of shoot and grain and oil yields, exhibiting great potential as an organic fertilizer for the sunflower cultivar Helio 250.

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