Colegio de Postgraduados

Yield of Cushaw squash (*Cucurbita argyrosperma* H.) with organic fertilizers

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ABSTRACT

Objective: to evaluate different doses of composted poultry manure and leachate applied to soil and foliage as organic fertilizers on the yield and yield characteristics of Cushaw squash (also known as Silver-seed gourd, and less frequently as creole squash).

Design/Methodology/Approach: ten treatments (T) were tested in four doses, 2.5, 5, 7.5, and 10 tons per hectare (Megagrams, Mg ha^{-1}) of composted poultry manure (C) applied to the soil at the beginning of crop cultivation, and leachates (L) at 50% applied to the foliage. A completely randomized design was used, with 15 replicates (fruits) per treatment.

Results: significant effects of compost and leachate treatments on the yield of Cushaw squash fruit were found.

Limitations/Implications of the study: it is suggested to evaluate more production cycles in order to identify the best treatments in further studies.

Findings/Conclusions: the combination of composts and leachates applied to the soil can be an alternative source of fertilization in the cultivation of Cushaw squash in Tabasco.

Keywords: poultry manure, compost, leachates, yield.

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INTRODUCTION

China is the first producer of squash worldwide with 7 325 193 tons (Megagrams, Mg) followed by Ukraine 1 097 780 Mg and Mexico occupies the 7th place with 729 201 Mg (FAO, 2022). One of several varieties grown in Mexico is the Cushaw squash (*Cucurbita argyrosperma* H.) which at domestic scale is grown in 17 states in the country. Campeche is the first producer (11 622 ha), followed by Guerrero (7867 ha); Tabasco is at the third place (7610 ha), then Zacatecas (6609 ha). These four Mexican states are the largest producers; the rest of states in Mexico grow squash in smaller quantities and smaller areas. In Mexico, squash cultivars are planted in different environments; frequently abusing soil because of an excessive use of agrochemicals to obtain production.

The addition of organic matter has the ability to improve soil properties. Leachate contains nutrients; also, microorganisms fix atmospheric nitrogen, releasing phytohormones to protect crops against plant pathogens, and control the pest population. The technological management of Cushaw squash is very variable. Differences are observed in a very wide range of production systems. Due to the lack of a fit-to-all technological set of strategies there are problems in each operation needed for this crop. So, there is an opportunity to transfer appropriate innovations to the local production system (Barrón & Rodríguez, 2020). In current agriculture, the intensive use and abuse of synthetic agrochemicals, such as fertilizers and biocides, has caused an ecological imbalance with the consequent degradation of ecosystems (Espinosa-Ramírez & Santiago-Mejía, 2023). The objective was to evaluate different doses of composted poultry manure applied to the soil, and leachate in foliar application, assessing their effects on the agronomic component and yield characteristics of Cushaw squash.

MATERIALS AND METHODS

Experimental site

This study is part of a research project that began in the spring-summer 2023 cycle with a trial of composts and manure leachate, which continued in the autumn-winter cycle of that same year (2023) in the fields of Campo Experimental Huimanguillo (INIFAP); located in the Huimanguillo-Cardenas road (17.847711, −93.396465 UTM), at 20 m altitude.

Soil and climate of the experimental site

The type of climate is warm humid (Am), classified by García (1964), which defines the conditions of the study *in situ*. The average maximum temperature was 32.8 °C and the minimum, 23.3 °C; rainfall was recorded as 585.8 mm during crop growing cycle (Figure 1).

The soil of the site is Fluvisol with a sandy-clay loam texture with a moderately acidic 5.8 pH, an average content of organic matter 3.2% and average total nitrogen 0.12%; phosphorus, 9.85 mg kg^{-1} and potassium 0.25 cmol kg^{-1}; As well as calcium 9.98 cmol kg^{-1}, magnesium 1.4 cmol kg^{-1}; and high contents copper and zinc (10.11 and 5.95 mg

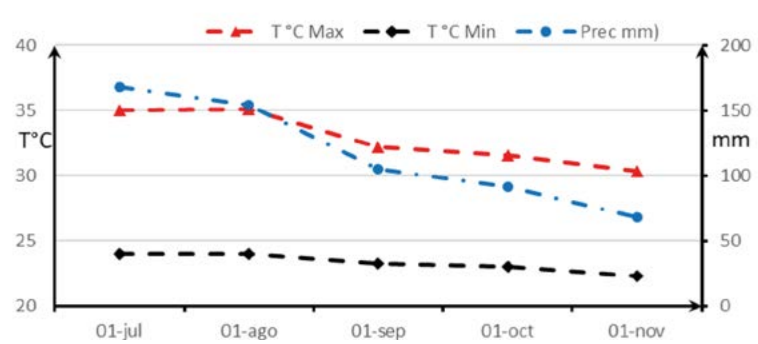

Figure 1. Rainfall (mm), maximum and minimum temperature (°C) during the spring-summer 2023 crop cycle. Source: Barrón F. S. (2023). Data from the climatological station of the C. E. Huimanguillo, Tabasco, Mexico.

kg^{-1}, respectively); an iron content 32.3 mg kg^{-1} that is considered medium, and low in manganese 0.98 mg kg^{-1}.

The laboratory analyses of the compost (C) and leachate (L) applied that summarize the nutrients provided to the squash are shown in Table 1 and Table 2, below.

The chemical fertilization was divided into two applications, the first was supplied 9 days after planting with 152 kg of diammonium phosphate (18-46-00); the second at 31 days with a mixture of 71 kg of urea plus 75 kg of potassium chloride, to attain a 60-75-45 formulation. In both applications the fertilizer was deposited around the plants, then covered with soil to minimize airborne losses.

Treatments and experimental design

Ten treatments were tested including the chemical (commercial) and zero controls (000); four doses 2.5, 5, 7.5, and 10 Mg ha^{-1} of composted poultry manure (C) and leachate (L). The size of the experimental plot was 30 m×40 m (width×length) with 10 rows of plants separated by 3 m each, where treatments were applied (Table 3). The arrangement was a completely randomized experimental design with 15 samples (fruits) per treatment. For treatments with composted poultry manure (C), it was mixed with the soil on the same date as the first application of the chemical fertilizer (this is, 16

Table 1. Chemical analysis of poultry manure composted (C).

pH	CE dS m^{-1}	MO	N	P mg kg^{-1}	K	Ca	Mg	Na	CIC	Fe	Cu	Zn	Mn
		%			cmol (+) kg^{-1}					mg kg^{-1}			
8.2	2.15	63	2.66	47.2	2.63	7.49	2.35	0.61	55.41	214.66	77.05	15.0	13.04

Table 2. Chemical analysis of manure leachate (L).

pH	CE dS m^{-1}	N	P	K	Ca	Mg	Na	Fe	Cu	Zn	Mn
		%						mg kg^{-1}			
7.9	2.40	1.29	2.70	1.70	2.29	0.71	0.17	131.06	49.24	10.28	10.81

Table 3. Treatments applied of compost (C) to the soil (S) and 50% leachate (L) to the foliage (F).

Treatments: Compost (C) and leachate (L) at 50 %	Abbreviation
T_1 Compost (C) 10 t ha^{-1}+leachate (L) to the soil (S)	TC10LS
T_2 Compost (C) 10 t ha^{-1}+leachate (L) to the foliage (F)	TC10LF
T_3 Compost (C) 7.5 t ha^{-1}+leachate (L) to the soil (S)	TC7.5LS
T_4 Compost (C) 7.5 t ha^{-1}+leachate (L) to the foliage (F)	TC7.5LF
T_5 Compost (C) 5 t ha^{-1}+leachate (L) to the soil (S)	TC5LS
T_6 Compost (C) 5 t ha^{-1}+leachate (L) to the foliage (F)	TC5LF
T_7 Compost (C) 2.5 t ha^{-1}+leachate (L) to the soil (S)	TC2.5LS
T_8 Compost (C) 2.5 t ha^{-1}+leachate (L) to the foliage (F)	TC2.5LF
T_9 Chemical control, (60-45-75) N-P-K fertilizer	TQm
T_{10} Control (000)	T000

days after sowing). Manure leachate at 50% concentration were supplied to the soil and foliage in three applications, the 1st at 23 days; the 2nd at 34 days, and the 3rd at 45 days after sowing.

Variables analyzed and statistical analysis

Fruit weight (g), each fruit was weighed on a scale (Electronic Compact Scala SF-400A, USA). Equatorial diameter of the fruit (cm), it was obtained from the most prominent middle part of the fruit. Polar diameter (cm), it was taken from the base of the middle part to the stem with a measure tape. Fruit shape index, it was obtained by the relationship:

$$Shape\ index = polar\ diameter / equatorial\ diameter\ (dimensionless)$$

Pulp thickness (mm), fruits were divided by their equatorial diameter, once the seed was extracted from the pulp, the thickness was measured in five fruits with a caliper (Truper®, Mexico). Seed weight (g) was measured as dry matter for each sample with the same balance; correlations were of seed weight versus polar diameter and equatorial diameter of the fruits.

In order to measure these variables, a randomized sample was collected with 20 replicates in each row of the 10 treatments. Then, with data an analysis of variance and a DMS test of means ($p \leq 0.05$) were done. Statistical analyses were performed on SAS®, version 9.3.

RESULTS AND DISCUSSION

Fruit weight (g)

The fruit weight variable did not show significant differences among treatments (DMS, $p \leq 0.05$). A trend from higher to lower value of fruit weight was observed in the foliar application treatments, which allows us to infer that the plant has the best response to foliar application of the treatments (Figure 2). It is worth mentioning that in cycles previously evaluated, the weight of squash fruits showed the same trend to the foliar applications of leachate. Villalobos *et al.* (2017) reported, in regard to the weight of Cushaw squash, 1600

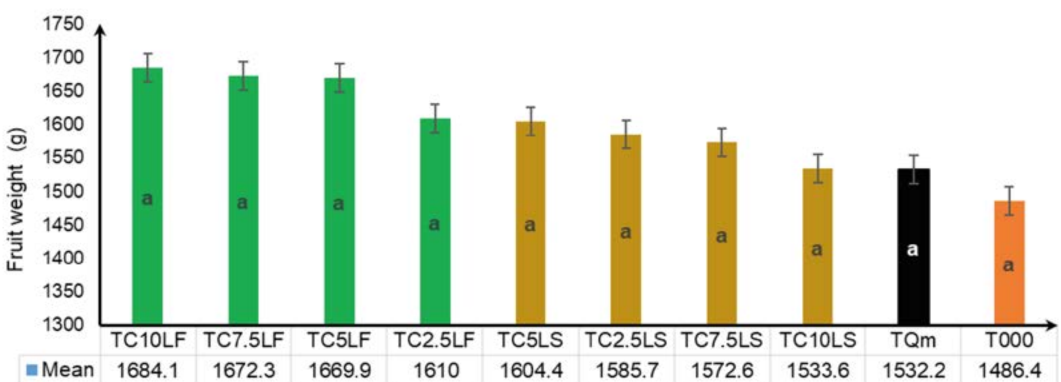

Figure 2. Average weight (g) of Cushaw squash fruits under combinations (on soil and foliar application) of fertilizer treatments; composted poultry manure and leachate at 50%.

g a value similar to the T2.5CLF and T5CLS treatments in our study,1640±99.20 EE and 1604±84.4 EE g, respectively. In another study, Tucuch-Haas *et al.* (2022) found no significant differences in the fruit weight of four varieties of Cushaw squash: Chihuahua, Aguascalientes, Yucatan and Norteno with an average of 1697.2 g; although the Yucatan genotype presented a greater number of fruits and a greater number of seeds with marketing quality. Ruelas *et al.* (2015), from 16 accessions of *C. argyrosperma*, reported an average fruit weight of 1060 g, comparable to the T10CLF treatment in our study, which was the highest (1684.10±111 g), the superior value by 62.94%. Whereas Cerón (2010) obtained an average fruit weight of *C. argyrosperma* H. of 710.13 g.

Pulp thickness (mm)

Figure 3 shows the effects of the different treatments on pulp thickness; significant differences were found among treatments (DMS, p≤0.05). The TQm presented fruits with a higher value with 25.20±1.50 mm, a significant difference of 24.6% compared to the T2.5CLS (19.00±1.92 mm), the latter value was the lowest (Figure 3). Regarding the other treatments, in this variable they were statistically equivalent, except the T7.5CLF (19.80±1.85 mm) when compared to the chemical control TQm (25.20±1.16 mm). In this variable, some results coincide with those reported by Tucuch-Haas *et al.* (2022), for the varieties of Cushaw squash Chihuahua, Aguascalientes, Yucatan and Norteno that reached 23.2, 22.6, 16.2 and 14.9 mm of pulp thickness, respectively.

Fruit polar diameter (cm)

Figure 4 shows the variable polar diameter of the fruit; there were no significant differences among treatments (DMS, p≤0.05) although the best response of this variable was obtained with the T5CLF treatment (51.00±1.25 cm), 4% larger than TQm (48.95±0.96 cm). Although it was not significant, all treatments improved this variable. Tucuch-Haas *et al.* (2022), in four varieties of Cushaw squash (*C. argyrosperma*), found an interval between 50.81 and 56.34 cm; compared to our study, TQm and T5CLF treatments coincided within that range (48.95, 51.00 cm) tough smaller and with no statistical difference.

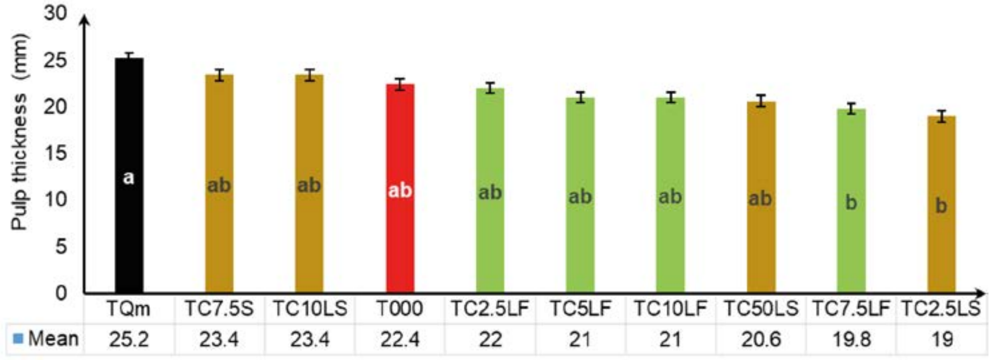

Figure 3. Pulp thickness (mm) of Cushaw squash fruits under combinations (on soil and foliar application) of fertilizer treatments; composted poultry manure and leachate at 50%.

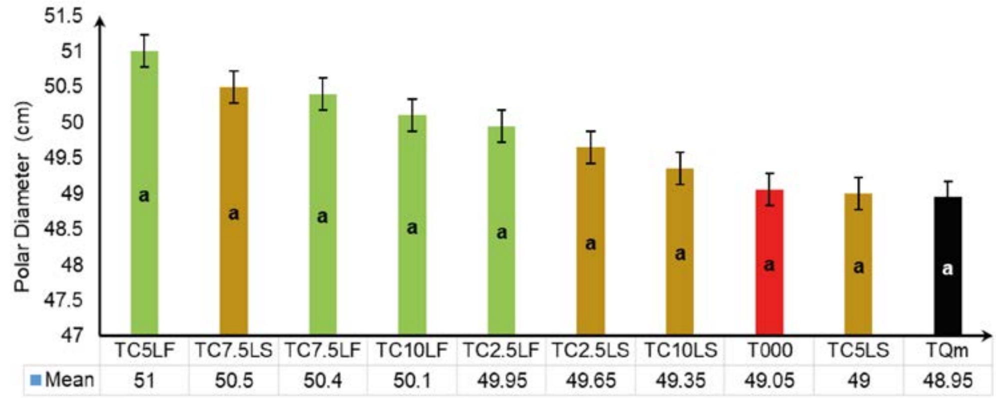

Figure 4. Average polar diameter (cm) of Cushaw squash fruits under combinations (on soil and foliar application) of fertilizer treatments; composted poultry manure and leachate at 50%.

Fruit equatorial diameter (cm)

Results obtained in the equatorial diameter variable of Cushaw squash fruit can be observed in Figure 5. There were significant differences among treatments (DMS, $p \leq 0.05$); the T7.5CLF with 53.80±1.12 cm exceeded that of the chemical control (TQm 51.10±1.20 EE) by 5%, and the zero control (T000) by 2.7%; this latter recorded an intermediate value (52.30±1.23 cm). The T10CLS (50.40±1.20 cm) showed the lowest record in the equatorial diameter variable of Cushaw squash fruit, compared to this the other treatments were better.

Tucuch-Haas *et al.* (2022), when evaluating four varieties of this squash, Norteno, Yucatan, Aguascalientes and Chihuahua, found fruit diameters 61.85, 60.08, 42.43 and 44.11 cm respectively, with significant differences. Villalobos *et al.* (2017) reported a fruit diameter of 50 cm in Cushaw squash that was lower when compared against those 53.80±1.12 cm of the highest value of T7.5CLF treatment in our study. Whereas Ruelas *et al.* (2015), found in *C. argyrosperma* an average fruit width of 13.0 cm, a value well below those obtained in this study. Lira-Saade (1995), in their morphological characterization of *C. argyrosperma* reported a range 14-25 cm in fruit diameter.

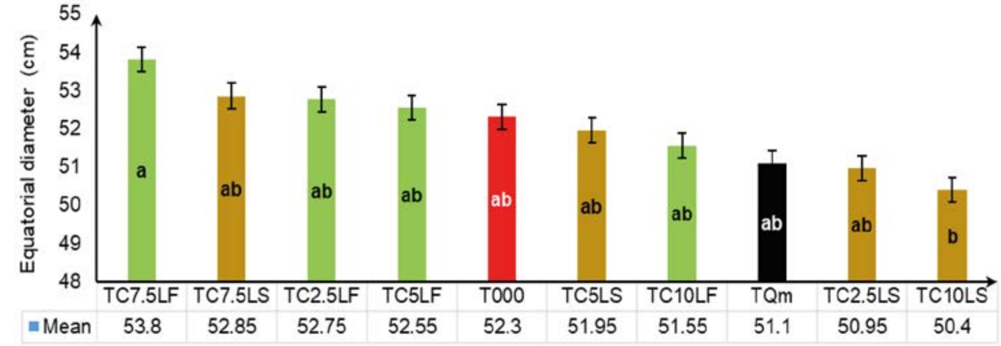

Figure 5. Equatorial diameter (cm) of *Cucurbita argyrosperma* fruits under combinations (on soil and foliar application) of fertilizer treatments; composted poultry manure and leachate at 50%.

Fruit shape index

Statistical differences among treatments (DMS, $p \leq 0.05$) were presented, as it is shown in Figure 6. Trends compared to control (T000), whose average was lower (0.93±0.01) in relation to the average of T10CLS treatment (0.98±0.01). This may be due to a lack of nutrients which affects the development of the fruit. The shape index of the polar diameter/equatorial diameter ratio according to the morphology (shape) of the fruit, a value below the unit (<1) was recorded. From which it is interpreted that fruits are oval or oblong (Lira-Saade, 1995). This index is obtained with the dimensions of fruit diameters (equatorial and polar), whose expression is polar D/equatorial D.

This ratio is an index to qualify the shape of the fruit, which should ideally have an equal ratio (1:1) in its dimensions, corresponding to the volume of a sphere. Overall, the indices obtained were greater than the unit (1), which indicates that the shape is slightly elongated to the fruit poles, thus giving it an ellipsoidal shape. Lira-Saade (1995) reported that the fruit shape of *C. argyrosperma* can be of several types; globose, oblate, ovoid, piriform, or clubs-form. In lemon, another type of fruit which is more homogeneous shape in lemon, García (2015) obtained index values in a range of 1.07 to 1.23 in fruits of Persian lemon grafted in *C. volkameriana*.

Seed weight (g)

Results of the seed weight variable are described in Figure 7; there were significant differences among treatments according to the test (DMS, $p \leq 0.05$). The best treatment was T10CLF with 68.78±4.35 g, surpassing control T000 (54.50±4.78 g) by 20.7%; with intermediate values in T2.5CLF, T10CLS and TQm treatments, 64.83±3.33, 62.47±4.49 and 62.39±4.75 g, respectively. This is, no statistical differences among those, but all of them statistically lower than T10CLF. Regarding the zero control (T000), it was surpassed by all the treatments under study.

FAO (2022) highlighted the importance of seeds for human sustenance and their genetic potential, improved over time, selected by producers for self-consumption and for sale, to improve production despite environmental problems. García and Dzul (2017) reported

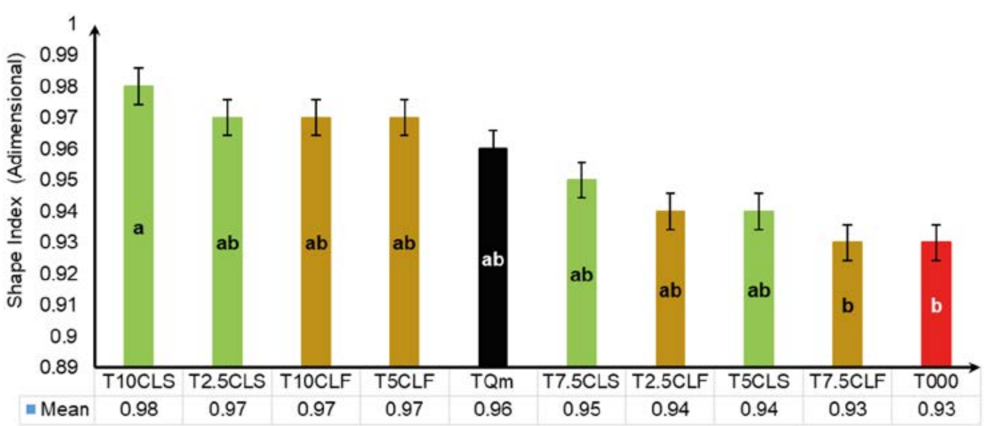

Figure 6. Fruit shape indices (dimensionless) of *Cucurbita argyrosperma* under combinations (on soil and foliar application) of fertilizer treatments; composted poultry manure and leachate at 50%.

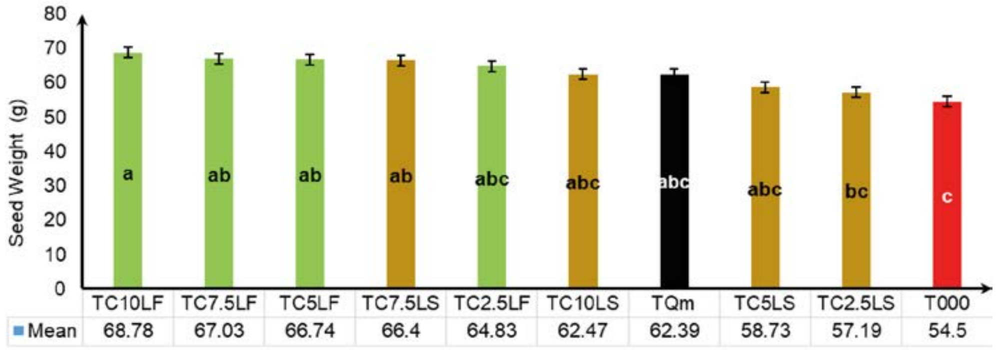

Figure 7. Average seed weight (g) per Cushaw squash fruit under combinations (on soil and foliar application) of fertilizer treatments; composted poultry manure and leachate at 50%.

70.09 g of seeds per fruit of Cushaw squash, those fruits were of flattened shape and fruit weight of 1728 g, values similar to those obtained with highest treatment tested here (T10CLF, 68.78 g of seeds per fruit, and 1684.10 g fruit weight). Ayvar *et al.* (2008) reported that with periodic application of chemical fertilizer to the soil, 59 g of dry seed per fruit can be reached, which significantly influences the number of fruits and the yield of dry seed, when fertilizers are supplied at the time of sowing, and then at intervals of 20 days.

Tucuch-Haas *et al.* (2022) reported that the Yucatan, Norteno, Chihuahua and Aguascalientes varieties can reach 66.54, 54.15, 24.63 and 18.4 g of dried seed per fruit respectively, those values are very similar and slightly higher than those obtained in this research. In addition, Villalobos *et al.* (2017), as a reference, reported 28 g as the weight of 100 seeds of good quality from fruits of Cushaw squash.

In this variable, it was possible to observe the effect of the application of leachate to the leaves (foliar application) with a slightly higher tendency on the application to the soil in this cycle, as it is shown (Figure 7). This may be due to the leachate effect, in addition to the residual effect of the poultry manure incorporated into the soil in the three cycles prior to cultivation. These results coincide with various reports mentioning that, as a characteristic effect of organic fertilizers applied to the soil. Where the soil acts as a nutrient reservoir and organisms continue to function by degrading organic matter and releasing nutrients for the next crop cycle (Sánchez, 2021). In other crops, as the application of leachate in maize at 55 days, in a dose of 500 L ha^{-1} originated the maximum biomass yield (37.5 Mg ha^{-1}), and in sorghum crop (4.8 Mg ha^{-1}) of grain yield (Patishtan *et al.*, 2023).

Results shown above, in the different variables can be taken as evidence of the goodness of these products. Improvements in growth and increased yields of Cushaw squash fruits could be due, in part, to a significant increase in soil microbial biomass following the application of compost to the soil in combination with leaf leachate, leading to the production of hormones or humates (humic deposits) in the compost and leachate that act as regulators of plant growth plus nutrient elements suppliers (Mkhabela *et al.*, 2020). Organic matter improves growth by lowering the pH of the rhizosphere, resulting in a better solubilization of nutrients, thus increasing availability to plants.

In addition, organic matter is a key source of minerals such as N, P, and K that improves soil structure and water-holding capacity (De los Santos *et al.*, 2022). The TC10LF treatment (10 Mg of compost+50% leachate, both applied to the soil) seems to favor nitrogen assimilation because to the presence of potassium and phosphorus (Table 1 and Table 2), which are essential elements for an optimal response to nitrogen (Alegbe *et al.*, 2020). Likewise, the synthesis of photosynthetic compounds is improved by increasing growth hormones and amino acids. These findings are in close agreement with the previous results obtained by Kaur and Rattan (2021) and Almudhafar and Obaid (2024) when studying the effect of the application of organic fertilizers in the cultivation of common squash (*Cucurbita pepo*), compared to chemical sources.

Correlations of seed weight vs. polar and equatorial fruit diameter

A correlation analysis of seed weight versus the variables of polar and equatorial diameter was made for characterizing the fruits; these results are presented in Table 4.

A trend to a higher correlation (r^2) of seed weight with fruit equatorial diameter was observed in all treatments. An example is observed in the scatter plots of Figures 8A and 8B, which shows the highest correlation of seed weight in T5.0CS treatment, both to fruit polar diameter (r^2=0.74) and to fruit equatorial diameter (r^2=0.79); contrasting with the T5.0CF treatment (r^2=0.19 and r^2=0.00, for those same variables).

Table 4. Ratio of seed weight versus polar and equatorial diameter of Cushaw squash fruits.

Treatment	Diameter	
	Polar	Equatorial
TQm	y=0.1607X+37.29, R^2=0.75	y=0.2009X+37.38, R^2=0.63
T000	y=0.138X+39.88, R^2=0.46	y=0.1544X+42.83, R^2=0.47
TC2.5LF	y=0.2111x+35.94, R^2=0.54	y=0.2747x+34.54, R^2=0.76
TC2.5LS	y=0.2009X+37.21, R^2=0.41	y=0.2027x+38.76, R^2=0.65
TC5LF	y=0.1614x+40.51, R^2=0.19	y=0.0174x+51.17, R^2=0.00
TC5LS	y=0.1592x+38.78, R^2=0.74	y=0.1650x+41.15, R^2=0.79
TC7.5LF	y=0.0854x+45.17, R^2=0.11	y=0.0684x+49.50, R^2=0.04
TC7.5LS	y=0.0464x+48.38, R^2=0.01	y=0.2171x+39.36, R^2=0.27
TC10LF	y=0.1288x+40.11, R^2=0.48	y=0.1954x+36.81, R^2=0.63
TC10LS	y=0.1561x+39.01, R^2=0.55	y=0.1358x+40.76, R^2=0.49

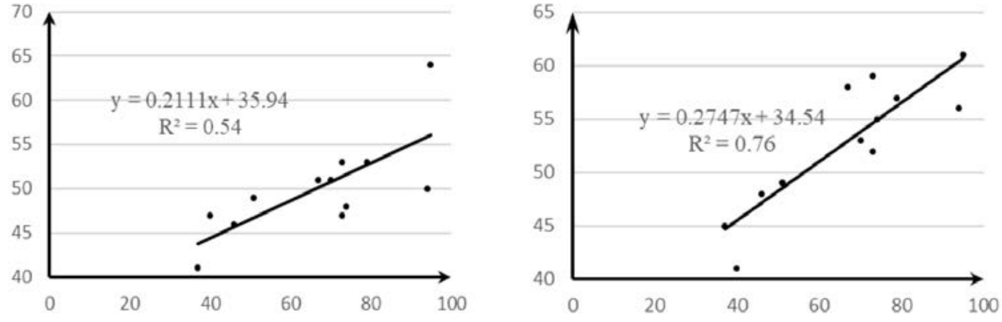

Figure 8. Regression plots between seed weight and the diameters (A: polar, and B: equatorial) of Cushaw squash fruits.

Overall, it appears that r^2 values were separated almost in half as slightly higher or slightly lower treatments, above and below the regression line. The statistics were obtained adjusted to a linear model (Figure 8A and 8B). These results contrast with those reported by Garcia and Dzul (2017), who found values up to r=0.90 in the correlation of the amount of dry seed per fruit of Cushaw squash; although that correlation was established against the weight of the fruits.

CONCLUSIONS

Composts incorporated to the soil, and leachates applied to the soil and to the foliage had effects on vegetative variables and fruit characteristics of Cushaw squash. The best treatments evaluated were combinations of composted poultry manure on the soil (5, 7.5 and 10 Mg ha^{-1}) plus the application to the soil and foliar of leachate at 50%.

When those combinations were supplied, the largest size of fruits, greater values of polar and equatorial diameters, as well as greater fruit weight were observed. The highest yield values of dry seeds of Cushaw squash were obtained with the treatments TC10LF, TC7.5LF, TC5LF and TC7.5LS, compared to the chemical control (TQm) and to the zero (T000) control.

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