Urban Agriculture as an Alternative for the Sustainable Production of Maize and Peanut

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Abstract: Currently agriculture has difficulty keeping up with the demand for food around the world, which has generated a boom in the development of sustainable alternatives for producing food and caring for the environment. Therefore, the present study aims to show a backyard system comprising 50 cm × 50 cm pinewood boxes where maize and peanut were tested under control and compost conditions. The experiments were carried out for nine months starting from compost production and the sowing of the crops, which were irrigated with temporary rain. The compost was produced by converting ~213 kg of organic residues into ~300 kg of mature compost. The fertilizer treatment consisted of two doses of compost (1 kg doses). The developing plants were compared between conditions in both crops. In addition, the nutritional values of the compost and soil were evaluated. Interestingly, the correlation analyses of the morphological properties of the soils showed that the effects of the nutrients were positively associated with the morphology of the crops studied. Finally, the yield produced for maize was 9 kg/m² and 6.6 kg/m² and that for peanuts was 184 g/m² and 73 g/m² under compost and control conditions, respectively. We consider that the development of new alternatives for producing food in times of crisis or situations of limited resources is necessary for the development of humanity and the care of the environment.

Keywords: compost; sustainable; backyard; urban agriculture; yield; nutrient mobility

1. Introduction

According to the FAO, climatic change, the demand for food, and pollution increases each year, and the environment and the cities suffer the consequences of using indiscriminate resources that affect nature, which generate crisis and pandemic situations that affect the quality of life for humanity. In times of crisis, such as the COVID-19 pandemic, the healthy and economic consequences are shown to the present day [1]. Agriculture has allowed food production and promotes humanity’s development; however, extensive technical crop production has degraded the environment and reduced biodiversity and ecosystem services [2].

Currently, fulfilling food demand is a global challenge [3]. Crop cultivation faces the challenges of worn-out soils, infections produced by phytopathogen-resistant antibiotics, pesticides, or metal salts, and the limited availability of water [3,4]. In addition, another aspect that limits food production is the area for production from the origin of agriculture until the present day; principally the soil is exploited and requires steps of restora-
tion to avoid process deforestation [5].

Now, agricultural food production should feed back to nature, understood as sustainable circular and urban agriculture, allowing the development and application of the techniques of friendly agriculture with the environment to decrease pollution during production and promote soil maintenance and restoration mediated by producing compost or vermicompost using organic waste [6,7].

Urban agriculture is an alternative during a crisis of food or sanitary emergencies (COVID-19 pandemic) and it promotes the efficient use of resources: space, waste management, use of water, and the growing of crops in the city to generate a positive impact to the planet, economy, and society [7]. These aspects are relevant in a changing world and an unstable economy, which cannot predict new catastrophes [3,8].

The present study aims to implement the production of maize and peanut in a backyard system with biofertilizer with compost obtained from organic waste from neighborhood locals in Campeche City, México. The experiments were performed in a control condition (absence of compost) and a compost condition (1 kg/box of compost), and the irrigation was performed during the temporal season (June–October 2021) in a backyard system consisting of 50 cm × 50 cm of pinewood boxes.

Our results showed significant differences in the physiological properties in both the crops and the soil nutritional values and showed the correlation between soil properties and morphological characteristics, highlighting the positive effect of nutrients in the soil, which are reflected in the plant’s morphology. This research showed the relevance of using organic waste to produce compost to reduce city pollution. It also shows a way to produce maize in a place with reduced space such as a city and with reduced resources, which could be considered a valuable alternative tool for society and research in times of crisis situations with limited resources.

2. Materials and Methods

2.1. Site description

This study was carried out in Campeche City, Campeche, Mexico. The global coordinates are 19°43'14" N–90° 24' 59" W. Campeche is a lower montane forest with an average ambient temperature of 28 to 38°C (Figure 1).
The native maize, named "Na'al Te'el Rojo," was obtained from the village Suctue in Hopelchén province, and the peanuts were from Kesté village, Campeche State, Mexico. Ten seeds of maize and peanut were considered as experimental units in each experimental box and were used in triplicate.

2.3. Organic composting

The method applied was layered stacked composting that reached five layers (Supplementary Figure S1A–B). The organic residues (vegetables and fruits) recollected each week from greengrocers were cut into smaller pieces for composting (Supplementary Figure S1C–D). Each layer was composed of 10 cm of dry material (sheet, stem, and dry waste garden) and 10–20 cm of green material; each layer was hydrated with 10 L of water and the subsequent layers were collocated until five complete layers formed the heap (Supplementary Figure S1A–B).

Finally, a ground cover was added, the heap was incubated for five days, and it was oxygenated with mediated mechanical homogenization, followed by the addition of more residues for new layers and the building of the heap anew. This process was performed each week for five months, finalized with one month of final compost maturation (Supplementary Figure S1A). During the process, the compost was monitored along with the environmental temperature.

2.4. Analyzed Soil and compost samples

For each box (experimental unit) a composite soil sample of 1 kg was taken prior to harvest for control and compost conditions. Three samples of 1 kg of mature compost and six composite soil samples were sent for nutritional analysis to the Fertilab laboratory (https://www.fertilab.com.mx/).
2.5. Experimental design

The experiment consisted of three experimental units (each box has dimensions of 50 cm × 50 cm of pine wood) by condition. Each experimental unit contains 10 seeds of maize and peanut under the same conditions correspondingly (control and compost). For compost conditions, two doses were used: first, when seeds were sowed and the second when plants started flowering; each dose corresponds to 1 kg of compost (Supplementary Figure S2).

2.6. Morphological characteristics

The evaluation of the characteristics of maize measured was the height (cm), stem width (cm), number of leaves (cm), root length (cm), and dry weight of the maize plants (kg).

In the case of peanuts, the plant height, root length, number of spikes, dry weight, and leaf area index (LAI) were calculated using the following equations:

2.6.1. Leaf area (la)

First, leaf area should be calculated with the following equation:

\[ la = \text{leaf area (average obtained from la calculated from all leaves of two plants)}; \]
\[ l = \text{length of leaf (corresponding to two plants)}; \]
\[ w = \text{width of leaf (corresponding to two plants)}; \]
\[ c = 0.75 \text{ (constant).} \]

\[ la = (l \times w) \times c \]

After each leaf was calculated the overall average was used.

2.6.2. Leaf area index (LAI)

\[ \text{LAI} = \frac{L \times P}{A} \]

2.7. Produce obtained from crops

The length (cm) and weight (kg) under each condition were measured for the maize cob. The total weight (g) of the peanuts was measured in a granary balance.

2.8. Maize and peanut yield

The yield was calculated for both maize and peanut using the following equation:

\[ x = \text{yield reported kg/m}^2; \]
\[ tw = \text{total weight of grains}; \]
\[ A = \text{sown area (in this study 0.25 m}^2). \]

\[ x = \frac{tw}{A} \]

2.9. Statistical analyses

The nutrition provided by the soil and compost samples was analyzed and the values obtained from the morphology of the plants are presented in results section; the average and standard error (SE) were obtained. The significance of the difference was evaluated through the mediated application of the Student’s t-test using Microsoft Excel compared to the control and compost conditions. The correlation analyses were realized using the Spearman coefficient and were performed with R version 4.1.1.1 and R studio.
3. Results

3.1. Compost production and yield

Previously, in order to sow the crops, we performed compost production and our results show the importance of this process; we monitored the temperature during the composting process. The compost showed an average temperature of 48°C compared to the registered environmental temperature of ~30°C (Figure 2A).

![Figure 2. Production of compost analyses. (A) Environmental (line red) and compost temperature (line blue) were evaluated for 16 weeks. (B) Organic residues obtained during 16 weeks correspond to the processed compost; the error bars describe the measurements in triplicate. (C) Yield compost obtained after 16 weeks of composting organic residues (yellow bar) used and the total quantity of obtained compost (orange bar). The error bars describe the assay in triplicate.](image)

The quantity (kg) of organic residues was collected and added for composting over 16 weeks, which revealed an average of 14 kg of organic waste per week (Figure 2B). Then, we reduced and transformed a total of ~200 kg of organic waste that was transformed into ~300 kg as the yield of mature compost (Figure 2C). In addition, we complemented the study with nutritional evaluation analyses (Table 1). Despite our results, the compost showed compost enrichment in Fe, Zn, B, and Mn. The analyses revealed acceptable pH levels, electrical conductivity, N, P, K, Mg, Na, S, Cu, and Ashes (Table 1).
Table 1. Nutritional evaluation of compost sample analyses was performed in triplicate and the standard error is shown.

<table>
<thead>
<tr>
<th>Determination</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>8.49 ± 0.00</td>
</tr>
<tr>
<td>Electric conductivity (d-S1 m)</td>
<td>1.90 ± 0.04</td>
</tr>
<tr>
<td>Total Nitrogen (%)</td>
<td>1.06 ± 0.00</td>
</tr>
<tr>
<td>Phosphorus (P) (%)</td>
<td>0.49 ± 0.01</td>
</tr>
<tr>
<td>Potassium (K) (%)</td>
<td>0.66 ± 0.00</td>
</tr>
<tr>
<td>Calcium (Ca) (%)</td>
<td>17.16 ± 0.39</td>
</tr>
<tr>
<td>Magnesium (Mg) (%)</td>
<td>0.27 ± 0.00</td>
</tr>
<tr>
<td>Sodium (Na) (%)</td>
<td>0.08 ± 0.00</td>
</tr>
<tr>
<td>Sulfur(S) (%)</td>
<td>0.27 ± 0.00</td>
</tr>
<tr>
<td>Iron (Fe) (%)</td>
<td>5249.33 ± 37.26</td>
</tr>
<tr>
<td>Cooper (Cu) (ppm)</td>
<td>10.76 ± 0.37</td>
</tr>
<tr>
<td>Manganese (Mn) (ppm)</td>
<td>275.33 ± 2.59</td>
</tr>
<tr>
<td>Zinc (Zn) (ppm)</td>
<td>113.36 ± 26.13</td>
</tr>
<tr>
<td>Boron (B) (ppm)</td>
<td>29.40 ± 21.92</td>
</tr>
<tr>
<td>Ashes (%)</td>
<td>81.06 ± 1.73</td>
</tr>
</tbody>
</table>

3.2. Experimental crops

Then, to assess the composting effect, we selected a model study of the crops: maize and peanut, and the experiment was performed in San Rafael, Campeche City, Mexico, during the COVID-19 pandemic in 2021. The design involved three experimental units (a box) for the control condition and three for the compost condition for each crop (Figure 3; S2). Then, in the first stage, the germination of the seeds was evaluated (Figure 3); in the case of the maize, the germination of seven seeds under the control condition (control) and 10 seeds under the compost condition (compost–maize) was observed, respectively (Figure 3, orange bars). For peanuts, the germination of eight seeds under the control condition (control) and seven seeds under the compost condition (compost–peanut) was observed, respectively (Figure 3, green bars).

![Figure 3. Germination analysis for compost–maize (orange bar) and control condition (orange bar). For peanut compost–maize (green bar) and control (green bar) conditions, both conditions and crops were compared with whole seeds sewn (blue bar). The error bar represents the reproducibility obtained from the triplicate assay.](image-url)

Then, we illustrate the process of growing the crops; our experimental proposal consists of a design using box pine wood (Figure 4A). The development of the crops in the box system was monitored (Figure 4B). The first growth stage under both conditions (Figure 4C–F), present for maize control and compost conditions (Figure 4C,D), and peanuts under the same conditions (Figure 4E,F), and the final growth stage under the control and compost conditions for the maize (Figure 4G) and peanut (Figure 4H).
Consequently, we evaluated the morphological characteristics (sheet number, stem width, height, and dry weight). The cob size and weight were evaluated for the maize. In peanut plants, the height, root length, pikes number, dry weight, leaf area index, and fruit (peanuts weight) in both conditions were evaluated (Table 2). In the case of maize, sheets and plant height under the compost condition (14.15 ± 0.19 and 2.98 ± 0.07, respectively) showed a significant difference compared with the control condition (Table 2). In the case of peanuts, we found a significant difference in spikes 11.00 ± 0.81, dry weight: 49.11 ± 2.14, and LAI: 1.86 ± 0.00 cm (Table 2).

Accordingly, we analyzed the nutritional properties of the sample soil used in the experiment where grown maize and peanut were under control and compost conditions (Table 3).
Table 3. Nutritional properties of soil analyses of maize and peanut in control and compost conditions were evaluated in the following aspects: properties of soil, relations between cations, cation exchange capacity, and soil fertility. The standard error was calculated for each measure analyzed for both conditions and the statistically significant difference (*) was performed using a Student’s t-test with a *$P < 0.05$; no significant difference was highlighted with ns.

<table>
<thead>
<tr>
<th>Properties</th>
<th>Determination</th>
<th>Control</th>
<th>*$P &lt; 0.05$</th>
<th>Compost</th>
<th>*$P &lt; 0.05$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class</td>
<td>Loamy</td>
<td>Loamy</td>
<td>ns</td>
<td>Loamy</td>
<td>ns</td>
</tr>
<tr>
<td>Saturation point (%)</td>
<td>48.5 ± 1.76</td>
<td>55 ± 2.12</td>
<td>ns</td>
<td>55.1 ± 2.19</td>
<td>ns</td>
</tr>
<tr>
<td>Field capacity (%)</td>
<td>25.85 ± 0.95</td>
<td>29.40 ± 1.13</td>
<td>ns</td>
<td>29.50 ± 1.20</td>
<td>ns</td>
</tr>
<tr>
<td>Permanent Wilting Point (%)</td>
<td>15.40 ± 0.56</td>
<td>17.45 ± 0.67</td>
<td>ns</td>
<td>17.55 ± 0.74</td>
<td>ns</td>
</tr>
<tr>
<td>Electric conductivity (cm/hr)</td>
<td>3.15 ± 0.17</td>
<td>2.05 ± 0.60</td>
<td>ns</td>
<td>2.05 ± 0.60</td>
<td>ns</td>
</tr>
<tr>
<td>Apparent density (g/cm³)</td>
<td>1.19 ± 0.00</td>
<td>1.10 ± 0.02</td>
<td>ns</td>
<td>1.05 ± 0.01</td>
<td>ns</td>
</tr>
<tr>
<td>pH (1.2 water)</td>
<td>8.08 ± 0.05</td>
<td>8.40 ± 0.00</td>
<td>ns</td>
<td>8.38 ± 0.17</td>
<td>ns</td>
</tr>
<tr>
<td>Total Carbonates (%)</td>
<td>36.95 ± 4.00</td>
<td>41.45 ± 3.57</td>
<td>ns</td>
<td>33.8 ± 1.76</td>
<td>ns</td>
</tr>
<tr>
<td>Salinity (Extract CE) (dS/m)</td>
<td>1.38 ± 0.02</td>
<td>0.65 ± 0.04</td>
<td>*</td>
<td>0.78 ± 0.01</td>
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<table>
<thead>
<tr>
<th>Soil properties</th>
<th></th>
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<tr>
<td><strong>Relation between Cations</strong></td>
<td></td>
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<tr>
<td>Calcium (Ca)</td>
<td>87.55 ± 0.03</td>
<td>84.40 ± 0.14</td>
<td>*</td>
<td>83.00 ± 0.14</td>
<td>*</td>
</tr>
<tr>
<td>Magnesium (Mg)</td>
<td>6.06 ± 0.01</td>
<td>8.09 ± 0.00</td>
<td>*</td>
<td>9.18 ± 0.00</td>
<td>*</td>
</tr>
<tr>
<td>Potassium (K)</td>
<td>3.70 ± 0.01</td>
<td>5.81 ± 0.03</td>
<td>*</td>
<td>6.00 ± 0.14</td>
<td>*</td>
</tr>
<tr>
<td>Sodium (Na)</td>
<td>1.75 ± 0.01</td>
<td>1.71 ± 0.14</td>
<td>ns</td>
<td>1.78 ± 0.42</td>
<td>ns</td>
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<table>
<thead>
<tr>
<th>Cation Exchange Capacity</th>
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</thead>
<tbody>
<tr>
<td>Organic material (MO) (%)</td>
<td>3.95 ± 0.03</td>
<td>4.91 ± 0.17</td>
<td>ns</td>
<td>5.72 ± 0.17</td>
<td>*</td>
</tr>
<tr>
<td>P-OLSEN (ppm)</td>
<td>144.50 ± 0.03</td>
<td>182.50 ± 3.18</td>
<td>*</td>
<td>193.50 ± 0.17</td>
<td>*</td>
</tr>
<tr>
<td>K (ppm)</td>
<td>388.50 ± 0.03</td>
<td>582.50 ± 3.88</td>
<td>*</td>
<td>600.50 ± 0.17</td>
<td>*</td>
</tr>
<tr>
<td>Ca (ppm)</td>
<td>4710.50 ± 0.03</td>
<td>4339.00 ± 31.82</td>
<td>*</td>
<td>4259.50 ± 0.17</td>
<td>ns</td>
</tr>
<tr>
<td>Mg (ppm)</td>
<td>228.00 ± 0.03</td>
<td>252.50 ± 2.47</td>
<td>ns</td>
<td>285.50 ± 0.17</td>
<td>ns</td>
</tr>
<tr>
<td>Na (ppm)</td>
<td>107.00 ± 0.03</td>
<td>100.80 ± 10.04</td>
<td>ns</td>
<td>104.00 ± 0.17</td>
<td>ns</td>
</tr>
<tr>
<td>Fe (ppm)</td>
<td>6.63 ± 0.03</td>
<td>8.76 ± 0.01</td>
<td>*</td>
<td>9.63 ± 0.17</td>
<td>*</td>
</tr>
<tr>
<td>Zn (ppm)</td>
<td>7.75 ± 0.03</td>
<td>7.99 ± 0.14</td>
<td>*</td>
<td>8.05 ± 0.17</td>
<td>ns</td>
</tr>
<tr>
<td>Mn (ppm)</td>
<td>2.62 ± 0.03</td>
<td>3.89 ± 0.02</td>
<td>ns</td>
<td>3.38 ± 0.17</td>
<td>ns</td>
</tr>
<tr>
<td>Cu (ppm)</td>
<td>1.17 ± 0.03</td>
<td>1.13 ± 0.02</td>
<td>ns</td>
<td>0.99 ± 0.17</td>
<td>ns</td>
</tr>
<tr>
<td>B (ppm)</td>
<td>0.79 ± 0.03</td>
<td>1.01 ± 0.01</td>
<td>ns</td>
<td>1.04 ± 0.17</td>
<td>*</td>
</tr>
<tr>
<td>S (ppm)</td>
<td>16.10 ± 0.03</td>
<td>1.40 ± 0.00</td>
<td>ns</td>
<td>2.09 ± 0.17</td>
<td>*</td>
</tr>
<tr>
<td>N-NO₃ (ppm)</td>
<td>95.35 ± 0.03</td>
<td>14.35 ± 0.67</td>
<td>*</td>
<td>22.95 ± 0.17</td>
<td>*</td>
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</table>

The results showed that the soil used in the experiments for both crops was loamy (Table 3). Concerning the soil fertilization, P-OLSEN (ppm) of 182.50 ± 3.18, K (ppm) 582.50 ± 3.88, Fe (ppm) 8.76 ± 0.01, Zn (ppm) 7.79 ± 0.14, and N-NO₃ (ppm) 14.35 ± 0.67 was found (Table 3). Then, we found a statistically significant difference for maize in
compost conditions regarding the aspect of the salinity, which was 0.65 ± 0.04. Another aspect evaluated was the relationship between cations, which showed that Ca/Mg was 10.40 ± 0.00. Regarding the cation exchange capacity, we found that Ca was 84.40 ± 0.14, Mg 8.09 ± 0.00, and K 5.81 ± 0.03.

In the case of peanuts, the compost condition for salinity was 0.78 ± 0.01 (Table 3). The relation between cations showed that Ca/K was 13.85 ± 0.03, Mg/K 1.53 ± 0.00, Ca/Mg/K 15.40 ± 0.07, and Ca/Mg 9.04 ± 0.01. Regarding the cation exchange capacity, Ca was 83.00 ± 0.14, Mg 9.18 ± 0.00, and K 6.00 ± 0.14.

For soil fertilization, it was found that MO(%) was 5.72 ± 0.17, P-OLSEN 193.50 ± 0.17 ppm, K 600.50 ± 0.17 ppm, Mg 285.50 ± 0.17 ppm, Fe 9.63 ± 0.17 ppm, B 1.04 ± 0.17 ppm, S 2.09 ± 0.17 ppm, and N-NO₃ 22.95 ± 0.17 ppm, which showed a statistical significance (Table 3). The results for maize and peanut under the compost condition compared with the control condition highlighted the statistically significant differences, with \( P < 0.05 \) (*) and \( P > 0.05 \) (ns) (Table 3).

Consequently, we performed the analyses of Pearson’s correlation of variables, which produced statistically significant differences (Figure 5).

Our results are presented in the correlation plot, which showed the scale Rho of Spearman values between the variables. This analysis compared the variables obtained from the morphological characteristics of the plants of both crops evaluated with the nutritional properties of soil samples analyzed. For the case of the maize, both conditions were evaluated using the number leaves, stem width, height, cob weight, and size analyzed in correlation with MO, P-OLSEN, K, Ca, Mg, Na, Fe, Zn, Mn, Cu, B, N-NO₃, and
the relationship between metals Ca/K, Mg/K, and Ca/Mg/K (Figure 5A–B). The case of the maize under control conditions showed that the K, Ca, Mg, Na, N-NO₃, and a combination of metals were positively related to the effect on the morphological characteristics of the maize plants (Figure 5A). The compost–maize condition found that the MO, P-OLSEN, and Zn affected the plants’ properties negatively, showing that the proportion of the other properties in the soil with the treatment of compost was positively related to the morphological plants and cob (Figure 5B).

In the case of the peanuts used as variables, morphological characteristics such as plant number, height, root length, spikes, dry weight, and LAI on peanut plants and the total weight of peanuts were obtained; these were correlated with MO, P-OLSEN, K, Ca, Mg, Na, Fe, Zn, Mn, Cu, B, N-NO₃, and the relationship between metals Ca/K, Mg/K, and Ca/Mg/K (Figure 5C,D). For the control condition, Ca, Mg, B, and N-NO₃ improved a plant’s number, height, and the number of spikes, but the dry weight and peanuts’ weight were positively correlated with almost all the properties except Ca, Mg, B, and N-NO₃ (Figure 5C). The peanut compost conditions showed that a plant’s number, height, spikes, dry weight, and LAI correlated positively with MO, P-OLSEN, Fe, Zn, Mn, Cu, and the relationship between metals, Mg/K, and Ca/Mg/K (Figure 5D). Only the root length was positively correlated with K, Ca, Mg, Na, N-NO₃, and Ca/K (Figure 5D).

Finally, we calculated the yield for the maize and peanuts produced from the proposed box system; maize was obtained at 6.6 kg/m² and 9 kg/m² for control and compost conditions, respectively (Figure 5). A representation of the cob produced is shown in Supplementary Figure S3. In the case of the peanuts, they were obtained at 184 g/m² for the control and x at 73 g/m² for the compost condition (Figure 6).

**Figure 6.** Yield of maize grains and peanut seeds determination for control and compost conditions were calculated for maize in control (orange bar), and compost–maize (orange bar) shown in kg/m². For peanuts, the yield obtained for control (green bar) and compost–peanut (green bar) was presented in g/m². The error bar represents the reproducibility obtained from the triplicate assay.

4. Discussion

From its origin to the present day, agriculture has been responsible for providing food for humans and animals for livestock production [5]. The techniques of traditional and extensive production are not enough to supply the demand for food around the world [9]. In addition, production is lost by limited water, the presence of disease resistance, high fertilizer prices, and excessively used soil creating degradation and malnourished soil [10]. These difficulties have promoted the emergence of new techniques and new places where agriculture is performed [6]. Currently, there is a boom in developing techniques that make efficient use of resources and that are friendly to the environment [6,11]. Sustainable urban agriculture is an alternative for producing more food with high quality in the city [11]. This kind of agriculture allows for the approach of using resources from the city (space, organic waste, and water) for promoting sustainability, producing food innocuously and with high nutritional value. However, other reasons have promoted the practices of alternatives to food production, one such case more recently being the COVID-19 pandemic, which stopped the development of humanity and
produced times of crisis where it was difficult to perform activities such as agriculture [12].

This project aimed to promote the use of organic waste and implement a system in the city to produce food in limited spaces and used models of maize and peanut, which are important food for the human diet [13,14].

Our research allowed us to reduce organic waste and transform it into compost that was used as a biofertilizer for the crops tested; organic compost is a natural tool that returns macro and micronutrients, minerals, and microorganisms to the environment that help the soil to produce Nitrogen and solubility and improves the adsorption of nutrients by plants [15]. Our results showed the achievable production of compost in six months in a tropical zone (Campeche, México) with an average temperature of 28-30°C, and each week we added mixed and new organic waste, which allowed us to improve the process and obtain compost [14–16].

Compost is an organic material with concentrated nutrients such as Nitrogen, phosphorus, potassium, and minerals, which can be solubilized easily and absorbed by radicle system plants. It is a technique that uses natural materials to maintain fertilized soils [16,17].

This research proposes a new method of producing maize and peanut in the backyard using pinewood boxes. In addition, we used what we had produced as fertilizer compost [16]. The compost quality is determined by a combination of different aspects: the carbon: Nitrogen (C/N) ratio of 30:1 and a moisture content of about 60% are recommended. Temperature is another crucial aspect of the production of compost-free pathogens [18]. The temperature during the thermophilic phase should be 54–55°C (above 40°C), which would guarantee that the compost would inactivate pathogen microorganisms [18]. Our results coincide with the quality of compost produced, which is interesting because it was produced in a short time, and still reached the quality parameters. An additional interesting aspect was the positive impact that the reduction of organic waste has on society.

Our results coincided with those reported by Shrestha Paliza et al., who described a two-year compost maturity experiment and compared it with synthetic phosphorus and Nitrogen; they showed that the compost contained a high amount of available phosphorus (P) and Nitrogen (N) using cultures compared to synthetic treatment [19]. Interestingly, the compost that we tested coincided with the reported compost quality and nutritional values, and producing compost to convert organic residues into biofertilizers is useful [18].

Then, the idea was to test the compost, for which we designed a box for growing maize and peanut as test crops. A limiting aspect was the space. Each box had dimensions of 50 cm × 50 cm, which could affect the development of the plant. In the case of maize, the space tested as normal for grown maize is described by Wenshun et al., who showed that a space of 0.54 m × 0.27m × 1.00 m obtained a good development but that if this is reduced to 0.20 m then this obtained a negative effect in the maize plants [20]. Our system allowed us to obtain maize plants of > 2.90 m, which could explain why the space did not affect the development of the plants; evidence of root development on the maize is shown (Supplementary Figure S3A). In addition, the seeds used were of native crops of Campeche; the maize and peanut may adapt to the box system because they are not extensive crops.

In fact, the morphology was not affected in the case of the maize in both conditions; however, we found significant differences in morphological properties associated with the impact of the compost fertilizer [21].

Our results coincided with those described by Kandil et al., who depicted the potential of organic manure to improve the production of Zea mays. The study revealed that the compost treatment described (0, 5, and 10 tons/ha) positively affected the plant height, ear length, number of grains/rows, number of grains/ears, and the weight of 100 grains and improved the yield [22].
In the case of peanuts, our results showed that the compost had a negative effect because major development was observed in the control condition of the peanuts. This was a mistake because space is important for the development of this plant [23]. The recommendation is 10 to 12 plants distributed in a groove; however, our crop was observed to have a more negative effect in compost conditions (Supplementary Figure S3B–C) [20,23]. Another aspect that could explain the negative effect on peanut plants was that the compost had the minimum quantity acceptable of Phosphorus, Boron, and Nitrogen, deficiencies of which affect growth, and Nitrogen deficiency symptoms include stunted plants with yellow and small leaves, which affects flowering and nodule formation [24].

Agegnehu et al. reported that the application of biochar and compost, or a combination of them, improved the development of peanut plants and enhanced the organic carbon present in the soil, the nutrients available for plants, and soil water retention, improving growth and crop yield [25]. However, our results for peanuts contradicted those described by Agegnehu et al., in addition, space was a factor that was even more important for the development of these crops [25].

Our study provided an alternative technique for producing maize and peanuts in the city. The availability of nutrients in the soil depends on the pH condition, quality, properties, and structure of the soil, and the availability of the principal nutrients helps in the growth of healthy plants [16,18].

The correlation analyses between the variables evaluated for each condition of the crops demonstrated the positive effect shown by the crops for the respective nutrients coinciding with those described for the function of each nutrient for maize and peanut, respectively.

Then, the nutrients evaluated in the soil were correlated with the morphological characteristics of the crops showing their effect on the plant's development, the soil properties, the relations between cations, and that the cation exchange favors the availability of micronutrients (Ca, Mg, Na, Fe, Cu, B, and S), which showed significant differences between the compared conditions in both crops. This explained the positive results observed in the development of the plants (Table 2), as these micronutrients are responsible for activating metabolism by developing plant protein synthesis (N, S), photosynthesis (Fe, Cl), DNA and RNA synthesis (P), enzyme activation (Zn, Cu, Ca, Mn, Ni), movement sugar (K), carbohydrate metabolism (B), respiration, and nitrogen fixation (Fe, Mo) [26].

The high pH in the compost condition could explain the low germination in the seed of peanuts compared to the control condition, which reduced the availability of zinc, iron, manganese, copper, cobalt, calcium, and magnesium, affecting the development of the plants in the case of the peanut [27].

Finally, the tested conditions showed that maize could be produced in a limited space. However, we think that the backyard system affected the development of peanuts. Since peanuts require a significant extension of soil in the pods when introduced in the soil to absorb nutrients and develop healthily, we believe that the compost and box system limited the development of the peanut plants, reflected in the low yield of the peanuts.

Our success story is that maize was produced with tall plants and good numbers of germinated seeds. Even though we did not find a significant difference in the yield produced in maize, the results provide an alternative for the sustainable production of this crop that is an essential part of the food base of the human population. The application of urban agriculture was described in a study in Sidney, Australia. Small-scale urban agriculture has a high yield but requires judicious input management to achieve sustainability [28]. In addition, the backyard production system was found to be related to the initiation of socioeconomic improvement in rural towns in Sinaloa, Mexico [29].
5. Conclusions

This study proposed a system for producing compost and using it as a fertilizer to produce, in this case, maize in the city; our research showed that the box system is an alternative for producing food that could be recommended for crops of the family Poaceae, which is a main principal ingredient in cereals; in contrast, this system is not recommended for legumes such as peanut. Finally, we consider that the development of new alternatives for producing food in times of crisis or situations of limited resources is necessary for the development of humanity and the care of the environment.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/agriculture13010059/s1, Figure S1: Compost obtained from organic waste: (A) Pile of mature compost; (B) Evidence of high temperature (~55°C) in the composting process; (C) Organic waste used for producing compost; and (D) An example of a layer of the compost pile method. Figure S2. Design of a backyard system comprising two crops for testing, two conditions for each, and our proposal using ten seeds per crop per condition. The point represents where two seeds were placed in each experimental unit (a box) by crop. Figure S3. Morphological characteristics of crops and cob. (A) Root developed from maize in the proposed backyard system; (B) Peanut plant grown in the absence of compost; (C) Peanut grown in the presence of compost; (D) Example cobs obtained from experiments performed in the backyard system.

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Data Availability Statement: The datasets generated and/or analyzed during the current study are available from the corresponding author.

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