Impact of Compost Application Rate on Lettuce Plant Growth and Soil Agrochemical Status

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Summary

One way to reduce environmental stress and safeguard soil fertility and ecological sustainability in crop production is by adding compost to the soil substrate. Supplying the soil with organic matter improves its chemical and physical characteristics, leading to better plant growth and development and increasing yield. The study presents a pot experiment with lettuce on leached cinnamon forest soil (Chromic Luvisol). Research has studied changes in soil NPK before and after vegetation and the effects of the compost on plant production and quality. Increasing the amount of compost in the soil substrate led to an increase in the fresh mass and yield of lettuce and to an increase in the accumulated N, P, and K (%) in the plant tissues ($R^2 = 0.91$, $0.96$ and $0.68$, respectively). After the experiment’s conclusion, the soils remained very well stocked in $P_2O_5$ content. The $K_2O$ stock in the soil was medium, i.e. when compost is applied, plant-available potassium increases relative to the initial soil. Total N remained very low; the applied composts provided large amounts of nitrogen for growing lettuce but did not leave the soil in good ecological status.

Key words

soil sustainability, *Lactuca sativa*, compost, nitrogen, phosphorus, potassium

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Introduction

Sustainable land use and soil fertility protection are our time's most significant challenges. Optimal fertilizer management and effective use of nutrients are crucial to obtaining maximum yield with high quality (Fageria, 2016). In vegetable production, the predominant use of mineral fertilizers is observed because of their precise chemical composition and rapid absorption by plants (Sady et al., 1995). However, according to Kapoulas et al. (2017), organic production can achieve a higher yield and better nutritional qualities of the produce. One of the main advantages of organic over mineral fertilization is the provision of nutrients to plants over a more extended period due to their gradual release, which is of key importance when planning and managing organic fertilization, according to Hernandez et al. (2015).

In recent years, there has been a growing demand and use of organic fertilizers and soil improvers as an alternative to conventional fertilization. Through them, the protection of soil fertility and ecological sustainability in crop production should be ensured (Martinez-Blanco et al., 2013; Demiraj et al., 2018; Vasileva et al., 2021).

Adding organic matter, vermicompost, and compost to the soil improves its chemical and physical characteristics, leading to better plant growth and development and increased yields (Stopes et al., 1996). According to Khater (2012), composts should be considered more as soil conditioners than fertilizers because of their high organic matter content (90-95%) and significantly lower nitrogen, phosphorus and potassium content than found in mineral fertilizers.

For optimal management and planning of organic fertilization, and the efficient use of plant nutrients, the proportion (and/or dosage) of organic compost: soil used for the preparation of the substrate and information on the effect of compost on subsequent crops are essential to avoid unnecessary soil fertilization (Lustosa Filho et al., 2015; Burnett et al., 2016).

In the present work, lettuce (Lactuca sativa L.) was chosen as a test crop because of its rapid growth and visible morphological changes. Lettuces are among the world's most widely grown and consumed leafy vegetables. As a crop with short vegetation, lettuce has specific soil nutrient requirements. Recommendations for optimal fertilization rates are described by Rankov et al. (1991) and are as follows: 40-80 kg N ha⁻¹, 50-60 kg P₂O₅ ha⁻¹, and 50-60 kg K₂O ha⁻¹.

More information needs to be provided on the effectiveness of substrate reuse in vegetable production. Data on the use of composts in the preparation of substrates and determination of the compost:soil ratio is of great importance for sustainable development.

The present work aims to evaluate the influence of different compost:soil ratios on some growth indicators and yield of lettuce and to follow the condition of the soil after the end of their vegetation.

Materials and Methods

The article covers a greenhouse pot experiment conducted on leached cinnamon forest soil (Chromic Luvisol) from Chelopechene, ISSAPP ‘Nikola Poushkarov’ field. The experiment duration was 45 days. Test variants containing 100, 200, and 300 g compost were prepared in pots with a capacity of 2 kg. The substrates were composted for 30 days, and 60% water humidity was maintained. The content of nitrogen, phosphorus, and potassium in the compost was 1.74% N, 1.50% P, and 0.30% K.

The soil before planting was defined as poorly stocked with mineral N (23.0 mg kg⁻¹) and medium stocked in terms of K₂O (21.9 mg 100 g⁻¹) and P₂O₅ (8.2 mg 100 g⁻¹).

The experimental scheme included four options:

1. soil without compost – control;
2. variant – 5% compost: 95% soil (100 g);
3. variant – 10% compost: 90% soil (200 g);
4. variant – 15% compost: 85% soil (300 g).

Each variant had three replications, with four plants in each pot from pre-produced seedlings. The yield and content of chlorophyll pigments were recorded. The concentration of total N was measured by the Kjeldahl (Horneck and Miller, 1998) method, and K₂O and P₂O₅ in the plants were determined by Stanchev et al. (1982). The content of ammonium and nitrate nitrogen in the soil was determined according to Keeney and Bremner (1966), and the content of K₂O, P₂O₅ in the soil was determined by acetate-lactate method (Ivanov, 1984) before planting and post-harvest. Multi-factor ANOVA and Duncan Multiple Range Test (DMRT) at the 5% confidence level were performed using Stat graphics Centurion statistical software product.

Results and Discussion

Deteriorating soil fertility is one of the main challenges facing agriculture today. One of the main factors in the chemical depletion of the soil is that it has continuous periods of exploitation to satisfy the food of the growing world population. On the other hand, excessive and unbalanced mineral fertilization is the reason for the nutritional imbalance in plants, a severe prerequisite to problems not only with the finished product but also with the environment.

Using compost increases the soil’s nutrient content and acts as a slow-release fertilizer, dynamically providing N, P, and K during plant growth (Purbajanti et al., 2016). Our experiment presents soil substrates with different ratios of compost:soil. The contents of the main macronutrients before planting the plants, following the influence of the compost, are shown in Table 1.

After composting, in all variants, there is an increase in the soil reaction, and the soil becomes neutral from/to slightly acidic. All variants have an increased content of NO₃-N, P₂O₅ and K₂O, and the change in nutrients follows in proportion to the percentage of applied compost.

According to some scientists, organic soil improvers are mainly a source of N and P since about 98% of N and between 33 and 67% of total P in the soil are bound to its organic matter (Fuente et
According to Serio et al. (2001), the gradual release of nutrients from the compost over a more extended period and the rapid growth of lettuces, especially during the last 2-3 weeks of their vegetation, positively affect yield formation. Fig. 1 shows a summary of the yields obtained in the present work. At variants of 5, 10 and 15% applied compost, there was a proportional increase in lettuce yield, the growth being 47, 69 and 101% higher than the control. The results are consistent with Folefack (2008), who reported that the lettuce yield increased by 21.9% when compost was applied. Brito et al. (2014) also indicated that compost application resulted in a 63% increase in lettuce yield. This beneficial effect of compost on lettuce yield may be due to higher soil nutrient status, increased activity of enzymes involved in the N and P cycle and improved soil physical properties (Trupiano et al., 2017). In addition, adding organic matter promotes better root development (Table 2), which helps absorb water and nutrients, and leads to increased yield (Brady and Weil, 2005; Ibrahim et al., 2011; Osoro et al., 2014).

The lowest yield was expectedly recorded in the control variants (95.18g) and the maximum - from the variant with 15% compost (191.56g). Mostafa et al. (2019) reported similar results – in a field experiment, they reported the highest yield at the highest compost rate (9t). They also observed a proportional increase in production as compost application increased.

The decisive factor in the purchase of vegetables is their visual appearance, mainly the product’s color, associated with their nutritional qualities and degree of ripening. In lettuce, the intense green color is related to chlorophyll pigments and is, therefore, one of the essential quality assessment indicators.

The content of photosynthetic pigments in lettuce at the end of the experiment was measured (Table 3). The data shows that the amount of applied compost does not significantly affect the pigment content of lettuce, similar to results reported by Chiconato et al. (2014) and Hernandez et al. (2015).

The use of compost improves the physicochemical and biological properties of the soil and increases the cation exchange capacity (CEC) and the available nutrients. In this way, plant growth and nutrient uptake are stimulated (Li et al., 2017; Mostafa et al., 2019).

Table 1. Soil analysis before and after experiment

<table>
<thead>
<tr>
<th>pH(KCl)</th>
<th>NO₃⁻N (mg kg⁻¹)</th>
<th>NH₄⁺N (mg kg⁻¹)</th>
<th>P₂O₅ (mg kg⁻¹)</th>
<th>K₂O (mg kg⁻¹)</th>
<th>pH(KCl)</th>
<th>NO₃⁻N (mg kg⁻¹)</th>
<th>NH₄⁺N (mg kg⁻¹)</th>
<th>P₂O₅ (mg kg⁻¹)</th>
<th>K₂O (mg kg⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before composting</td>
<td></td>
<td></td>
<td>After vegetation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>5.92</td>
<td>18.7</td>
<td>4.3</td>
<td>8.19</td>
<td>21.9</td>
<td>6.23</td>
<td>0.76</td>
<td>1.46</td>
<td>8.9</td>
</tr>
<tr>
<td>1</td>
<td>6.22</td>
<td>56.6</td>
<td>0.43</td>
<td>8.57</td>
<td>23.8</td>
<td>6.59</td>
<td>6.03</td>
<td>1.73</td>
<td>35.4</td>
</tr>
<tr>
<td>2</td>
<td>6.52</td>
<td>120.0</td>
<td>1.19</td>
<td>29.1</td>
<td>29.8</td>
<td>6.71</td>
<td>3.66</td>
<td>1.23</td>
<td>61.2</td>
</tr>
<tr>
<td>3</td>
<td>6.64</td>
<td>138.0</td>
<td>0.49</td>
<td>48.7</td>
<td>31.2</td>
<td>6.71</td>
<td>3.67</td>
<td>1.11</td>
<td>66.0</td>
</tr>
<tr>
<td>4</td>
<td>6.71</td>
<td>159.0</td>
<td>0.39</td>
<td>77.5</td>
<td>33.3</td>
<td>6.82</td>
<td>3.67</td>
<td>1.11</td>
<td>66.0</td>
</tr>
</tbody>
</table>

Note: * 0. Initial soil, 1. Control, 2. 3% Compost, 3. 10% Compost, 4. 15% Compost.
The lowest NPK content in the lettuce was recorded in the control variants without added compost (Fig. 2). The total nitrogen content in lettuce plants varied from 1.31 to 2.60%, within limits described in the literature of 2.5-4% (Mitova and Marinova, 2012; Zabochnicka-Swiatek, 2019) and in sync with the fact that plant N concentration followed compost N content. In other words, its content in plants increases as its content in compost increases. The higher percentage of compost in the soil substrate explains the maximum reported total nitrogen content in the lettuce from the variant with 15% compost input. Furthermore, Fig. 2 clearly shows the relationship between total nitrogen concentration in lettuce and % added compost ($R^2 = 0.91$).

The $P_2O_5$ content of lettuce is about 0.2%, but some authors cite a range of 0.4-1.0% (Hernández et al., 2010). In the present work, the concentration of $P_2O_5$ in plants varies from 0.29-0.46%, with the maximum value reported from variants with 15% compost (Fig. 2). The good stocking of the soil after the introduction of high % compost (Table 1) and the amounts of compost significantly influence the uptake of phosphorus by lettuce with $R^2 = 0.96$ (Fig. 2), which may be due to the type of compost used – well-rotted. According to Cooperband et al. (2002), the maturity of the composts significantly affects the plants’ mobilization and phosphorus uptake. According to them, immature compost leads to the immobilization of $P_2O_5$ in the soil. Using 15% compost gives
maximum values – 4.4%, but in all variants, the reported values were lower than those recommended by Jones et al. (1991) – 6%.

The influence of the compost:soil ratio on the content of $K_2O$ in lettuce plants is the lowest – the coefficient of determination is 0.68; increasing the amount of applied compost would, to a lesser extent, lead to an increase in the accumulated potassium in lettuce (Fig. 2).

Soil samples were taken after the completion of the experiment to assess the soil status. The data is summarized and presented in Table 1. Under all variants, a slight increase in pH was observed compared to the initial soil and the soils after composting (Table 1).

The NO$_3$-N content of the initial soil, 18.7 mg kg$^{-1}$, significantly increased after composting (Table 1). Lettuce is a plant that prefers NO$_3$-N as a nitrogen source and is easily leached by irrigation water. After harvesting, the NO$_3$-N content in the soil was extremely low in all variants – from 0.76 to 3.67 mg kg$^{-1}$ (Table 1). However, there was an increase in the content of NH$_4$-N at the end of the experiment (Table 1).

Low total nitrogen was measured in all variants after the harvest. Applied composts provide nitrogen for plant growth and development but are insufficient to leave the soil in good condition after the growing season. When planting the next crop on these soils, it is necessary to perform nitrogen fertilization or feeding.

The reported content of P$_2$O$_5$ in the soil in the control variant before and after the experiment shows a slight increase compared to the initial soil (8.57 mg 100 g$^{-1}$; 8.90 mg 100 g$^{-1}$ and 8.19 mg 100 g$^{-1}$) - the phosphorus supply of the soil is medium. The data shows that using compost significantly improves the concentration of P$_2$O$_5$, and there is a significant increase in all composted variants. After harvesting the lettuce, the soils remained stocked with phosphorus, with maximum values at 15% compost (66.0 mg 100 g$^{-1}$) (Table 1).

After the experiment ended, the soil was medium-stocked with K$_2$O, i.e. when compost was applied, the potassium available to the plants increased (Table 1), but as a potassium-loving crop, lettuce absorbed relatively high amounts. Nevertheless, the K$_2$O content in the composted variants after the plants were harvested was higher than that measured in the initial soil (Table 1). Moreover, maximum values were recorded for potassium when applying 15% compost (24.3 mg 100 g$^{-1}$).

**Conclusion**

Using compost has proven to improve the soil’s nutritional status. After composting, the contents of NO$_3$-N, P$_2$O$_5$ and K$_2$O increased in all variants, and the change was proportional to the soil:compost ratio.

The gradual release of nutrients from the compost during the lettuce vegetation has a positive effect on the formation of their yield. The results obtained in the present work show that increasing the amount of compost in the soil substrate leads to an increase in fresh biomass and lettuce yield. Compared to the control, the yield increased by 47, 69, and 101% for the composted variants, proportional to the amount of the compost applied (5%, 10%, and 15%).

After harvest, the soil remained with an insufficient stock of total nitrogen, i.e., the applied composts provided nitrogen during the lettuce vegetation but were insufficient to leave the soil in good condition after the end of the vegetation. When planting the next crop on these soils, it is necessary to apply nitrogen fertilization. The soil, however, remained well stocked in terms of P$_2$O$_5$ and K$_2$O content, and subsequent crops could be grown without fertilizing with these nutrients.

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References


