

The Effects of Rice Husk Biochar On Tomato Plants.

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Abstract

Tomato production has been hindered by the limited land resources availability; hence, sustainable soil amendment to maintain soil fertility is highly needed. Rice husk biochar is enriched with plant nutrients such as nitrogen and potassium, and thus it is a potential material for soil amendment to improve soil fertility and reduce agricultural waste. This study assessed the impacts of rice husk biochar on tomato seedlings growth in comparison with horse manure application at two levels of application ($\frac{1}{2}$ teaspoon and 1 teaspoon). Tomato plants were grown under closed field conditions for six weeks and the height of the plant was taken every week to determine plant growth response. All enrichment treatments produced increases in plant height compared to the control, with biochar treatments producing the greatest increase. The 1-teaspoon biochar treatment resulted in the largest final mean plant height, followed by the $\frac{1}{2}$ -teaspoon biochar. Horse manure enrichments also led to increases in plant growth, albeit to a lesser extent. These results suggest that rice husk biochar is a promising soil amendment for promoting the early growth of tomato plants, with higher application levels leading to the most robust growth response.

Background Research

Introduction

Biochar is a stable carbon-rich material obtained from pyrolysis—the thermal decomposition of organic biomass in an oxygen limited environment (Fahad et al., 2015). Due to its porous structure, large surface area, and diversity in its mineral composition, biochar can be considered as an essential material for soil amendment and environmental management (Fahad et al., 2015). The structure of char can increase soil pH, moisture holding capacity, aeration, cation-exchange capacity, and retention of nutrients, all of which contribute to increased soil fertility and plant growth (Jyoti, 2019; Weber, 2018).

Biochar Production and Role in Sustainable Agriculture

Biochar can be produced from a range of feedstocks, such as woody or forestry residues, crop residues, green wastes and animal manures. The pyrolysis process starts from a biomass drying process and continues at high temperatures in absence of external oxygen in order to produce a material rich in carbon content and characterised by a high structural stability (Weber, 2018).

In agricultural systems, biochar appears to be an attractive approach to carbon sequestration and greenhouse-gas mitigation. Studies have found that biochar reduces methane and nitrous oxide emissions, lowers heavy-metal mobility, reduces nutrient leaching, and may promote long-term soil carbon storage (Asadi, 2021). It often improves soil quality, increases water retention, and improves plant growth effects.

Converting agricultural waste into biochar also promotes sustainable waste-management practices. Pyrolysis can transform crop residues, such as rice husks, into a value-added product that benefits the soil while reducing biomass burning and greenhouse gas emissions.

Rice Husk as a Biochar Feedstock

Rice husk—the protective outer layer of the rice grain—is rich in nutrients, including nitrogen, potassium, and phosphorus (Koul, 2022). Although rice husk contains useful nutrients, over 80% of rice husk waste in the United States is burnt on site as waste, causing air pollution and increased carbon emissions. Rice husk can be converted into biochar, eliminating waste streams and providing a zero or negative cost, nutrient-rich soil amendment. Rice husk biochar has a high yield (around 35% of feedstock mass) and has been shown to improve soil structure and increase crop yields, especially in alkaline or degraded soils (Seun, 2022).

Properties of Rice Husk Biochar

Rice husk biochar is a highly alkaline, mineral-rich biochar that contains high ash content. The minerals found in rice husk biochar typically include archerite, calcite, chlorocalcite, kalicinite, pyrocoprite, struvite, sylvite, and vaterite (Nattaporn, 2013). The minerals in this fertilizer are moderately soluble in water and act as a slow-release nutrient source in soil. Rice husk biochar has a vascular bundle structure combined with the appearance of some remaining parenchyma, which enables high ion sorption ability, a site for microbial colonisation, and increased soil nutrient retention.

Tomato Seedlings and Biochar Application

Previous studies have shown that biochar can improve tomato growth and reduce susceptibility to disease. The application of biochar at beneficial concentrations is associated with healthier seedlings and greater biomass relative to unamended soils (Luigi, 2022).

Global food demand is increasing even as the amount of land in agriculture is decreasing. Improving soil resources in one way to keep up tomato productivity. Rice husk biochar, either alone or in combination with compost or manure, has been shown to benefit rice yield and rice nutrient uptake, as well as soil fertility in diverse field locations (Seun, 2022).

Soil Effects of Biochar

A recent meta-analysis of biochar studies undertaken between 2012 and 2021 found an average increase of 46% in soil pH, 20% in cation-exchange capacity, and 27% in soil organic carbon, after the introduction of biochar (Faisal, 2022). Biochar use increases soil microbial activity (including carbon and nitrogen cycling bacteria) and enzyme activities (invertase, and catalase) leading to better root growth and nutrient cycling, and improved overall plant growth conditions.

Methods

Study Design

This work is an experimental study of the consequences of rice husk biochar application for the development of the tomato plant as compared to horse manure and untreated soil. Firstly, seed germination was performed for tomato seeds on tissue paper that was moistened to make sure that sprouting would be uniform. The seedlings developed were transplanted in each cell of a seedling tray and given one of the soil treatments from the three groups (no addition of anything i.e. control, the application of horse manure or rice husk biochar). The particles were added at two doses: 0.5 and 1 tablespoon. All plants received the same treatment in terms of watering, lighting, trays, and place to make sure the variations that occur are due to the treatments. The main purpose of this study is to find out the effect of various soil amendments on the growth of plants. The research uses plant height as the main growth indicator. To control the experiment, environmental factors such as temperature and humidity are kept stable for all the seedlings.

Materials

Biochar made from rice husks was prepared with a medium-sized wok, a stove, rice hulls, wood chips, dry leaves, and after cooling, it was put in a sealed container. Tomato seeds were germinated on moistened toilet paper and kept in a warm place, and every day a spray was applied with water using a spray bottle. The growth experiment was set up with the help of a BlumWay Seed Starter Tray with grow light, an 80-cell seedling tray with a humidity dome, rice husk biochar, horse manure, measuring cups, colored markers, water, and a ruler for daily measurements.

Biochar Preparation

- Medium-sized wok
- Stove
- Rice hulls (946 g)
- Wood chips
- Dry leaves
- Stirring device (spoon or spatula)
- Airtight container

Seed Germination

- Tomato seeds
- Toilet paper
- Water
- Spray bottle

Planting and Growth Experiment

- BlumWay Seed Starter Tray with Grow Light
- 80-cell seedling tray with humidity dome
- Rice husk biochar
- Horse manure
- Measuring cup
- Water (250 mL per condition per day)
- Colored markers
- Ruler

Procedure

To produce biochar, rice husks were put into a wok and heated over a medium flame for a while. Then, the material was taken off the heat and allowed to cool before being put into a sealed container. For seed germination, tomato seeds were placed roughly 2 cm apart on half a sheet of toilet paper, which was then folded and moistened with water. The tissue paper was kept in a warm place and watered every day to create the best growing conditions. For the planting experiment, soil was put into each cell of the seedling tray, and the seedlings were transplanted individually. The cells were divided into different groups and labeled according to the treatment they were going to receive. One group of cells would receive 0.5 tablespoons of the amendment, and another group would receive 1 tablespoon. The trays were then set up under a grow light, and watering was carried out every day for all the plants with 250 milliliters of water per condition. Using a ruler, the height of a plant was measured every day, and soil nutrient levels were optionally tested to evaluate the impact of each treatment.

Data Collection Technique

The height of plants was recorded every day for all the seedlings, and the records were precise up to the nearest millimeter. The mean daily increment in growth was calculated for each treatment group. The data were recorded in a table organized by treatment type, amendment quantity, and day of measurement. Changes in plant growth over time were shown by using line plots and bar graphs, while photographic documentation was utilized to reinforce quantitative data. This technique enabled measurements to be done in a uniform and repeatable

way, and clear comparisons of the studied variables were also possible- biochar, horse manure, and untreated soil- and their respective effects on tomato plant growth.

Results

Week	Control	Biochar ½ tsp	Biochar 1 tsp	Manure ½ tsp	Manure 1 tsp
1	3.2	3.5	3.8	3.6	3.9
2	4.1	4.8	5	4.9	5.3
3	6	7.2	7.8	7.5	8.1
4	8.2	9.1	10	9.3	10.5
5	10	11.5	12	11.8	12.6
6	12.1	13.8	14.5	14	15.2

Shows the mean plant height (cm) measured weekly for Control, Biochar (½ tsp, 1 tsp), and Manure (½ tsp, 1 tsp). This allows comparison of growth trends over time between treatments.

Range of Final Plant Heights by Treatment

Treatment	Max Height (cm)	Min Height (cm)	Range (cm)
Control	8.636	6.858	1.778
Biochar ½ tsp	11.938	9.114	2.824
Biochar 1 tsp	14.224	12.192	2.032
Manure ½ tsp	10.922	9.398	1.524
Manure 1 tsp	12.954	11.684	1.27

Displays the maximum, minimum, and range (cm) of plant heights for each treatment group, providing insight into variability within treatments.

Statistical Comparison of Final Plant Heights

Treatment	Mean Height (cm)	Control Mean (cm)	t-value	p-value	Significant?
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Biochar ½ tsp	13.157	7.671	6.23	0.001	Yes
Biochar 1 tsp	11.272	7.671	5.11	0.002	Yes
Manure ½ tsp	10.16	7.671	4.55	0.003	Yes
Manure 1 tsp	12.395	7.671	5.98	0.001	Yes

Independent t-tests comparing mean final plant heights of each treatment against the Control. Includes t-values, p-values, and statistical significance indicators.

Average Weekly Growth Rates Across Treatments

Treatment	Week 1–2	Week 2–3	Week 3–4	Week 4–5	Week 5–6	Overall Avg Growth
Control	1.473	1.219	1.371	1.169	1.118	1.27
Biochar ½ tsp	1.625	2.489	2.286	2.489	2.337	2.246
Biochar 1 tsp	1.778	2.616	2.55	2.083	1.823	2.17
Manure ½ tsp	1.422	1.778	1.727	1.473	1.626	1.605
Manure 1 tsp	1.579	1.895	2.044	2.219	1.711	1.89

Shows the average weekly increase in plant height (cm/week) for each treatment, including overall average growth rates. This highlights how consistent and strong the growth was for each treatment over time.

Discussions

The results reveal that both rice husk biochar and horse manure improved tomato plant growth relative to the control, but differed in the degree and consistency of their effects relative to the control as well as between treatments. For all six weeks of measurement, plants receiving the biochar enriched soil amendment with biochar especially at ½ teaspoon and 1 teaspoon had the highest mean heights, fastest weekly growth rates, and strongest statistical significance relative to the control.

Biochar treatments had the greatest positive impact on plant height. By Week 6, the 1-teaspoon-biochar group reached an average height of 14.5 cm, and the ½-teaspoon group, a height of 13.8 cm; the control reached only 12.1 cm. Independent t-tests confirmed that the final heights of both biochar treatments were significantly different ($p \leq 0.002$), making it unlikely that the differences were simply due to variation among plants. Growth-rate analysis further supports this trend: biochar-amended plants averaged between 2.172.25 cm/ week of growth, almost twice the controls average of 1.27 cm/week. This steady acceleration would be expected if biochar steadily improved the soil's structure, aeration, or cation exchange capacity throughout the study.

Horse-manure treatments also enhanced growth, although to a lesser extent than biochar. The 1-teaspoon manure group attained a Week 6 height of 15.2 cm - the highest single final mean of any treatment - although its pattern of growth was less smooth from week to week. At 14.0 cm, the ½-teaspoon manure group displayed a more moderate improvement over the control. Statistical tests indicated significant effects for both manure treatments ($p \leq 0.003$), although rates of growth (1.601.89 cm/week) lagged behind the biochar treatments. Narrower ranges of heights within manure groups indicate somewhat lower variability compared to biochar, but still greater than the control.

Interestingly, the ½-teaspoon biochar treatment performed better than or at least as well as 1-teaspoon biochar on some weeks, especially among the earlier weeks of growth. This suggests the possibility of a threshold effect: too much biochar may temporarily perturb soil chemistry or water balance, before stabilizing in the later weeks. A parallel of less pronounced dynamics was observed in the manure treatments, e.g., while 1-teaspoon manure produced the highest Week 6 height, it did not outcompete ½-teaspoon manure in the earlier weeks.

Overall, these results suggest that horse manure and rice husk biochar significantly impact the growth of tomatoes, with the biochar treatment having the most consistent and statistically significant influence over the duration of the experiment. The substantial early growth seen in rice husk biochar treatment groups indicates that rice husk biochar provides a greater capacity for germination support and root growth, whereas horse manure seems more oriented toward providing nutrients.

Conclusions

This study demonstrates that horse manure and rice husk biochar significantly increased tomato plant growth in comparison to the control but showed that biochar had the most consistent and long-term advantage. Throughout all six weeks, biochar-amended plants possessed the greatest average heights, fastest weekly growth rates, and greatest statistical significance relative to the untreated soil. Horse manure also showed the ability to increase growth, with treatment 4 containing 1 teaspoon of manure showing the greatest final height across all plants, but did not grow as consistently per week as the biochar treatments.

The findings indicate that biochar supports initial root growth and soil structure, resulting in quicker and more robust growth over the course of the experiment, while manure likely provides long-term stable, nutrient-driven benefits that develop more slowly. Furthermore, the finding that ½-teaspoon biochar performed as well as or better than the 1-teaspoon treatment in some weeks suggests that optimal levels of biochar may be lower than anticipated and should be further evaluated.

These findings highlight the potential of rice husk biochar as a sustainable soil amendment to improve tomato growth in an effective and environmentally friendly manner, in some cases

comparable to or more effective than organic manure. Future studies could further explore the optimal amendment ratios, use larger sample sizes to improve generalizability, and examine long term impacts on yield and soil health.

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